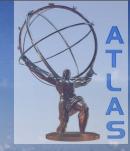
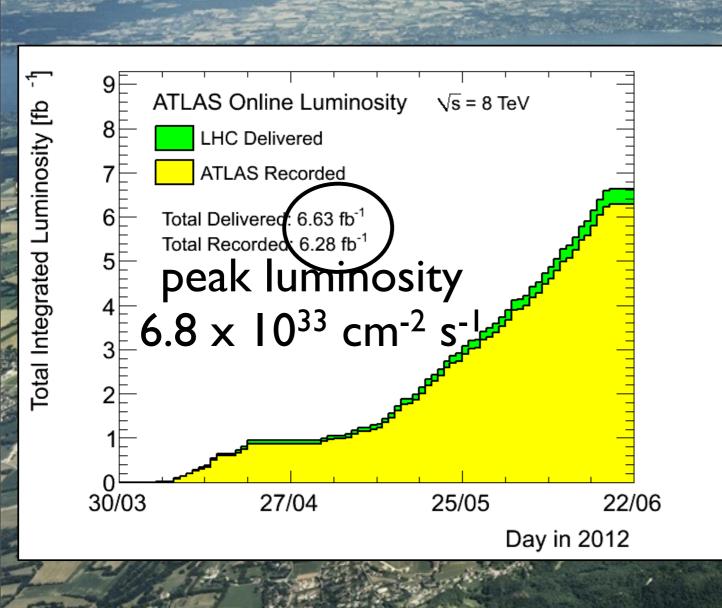






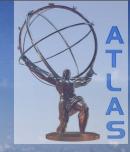
### The LHC

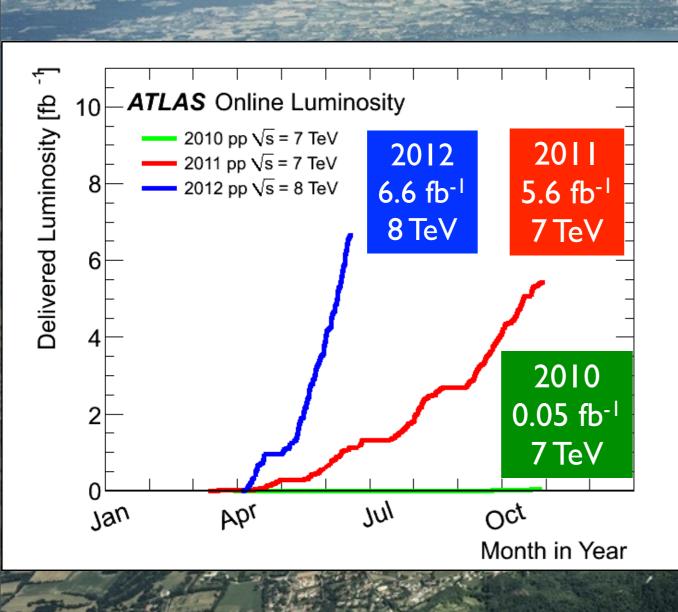






### The LHC

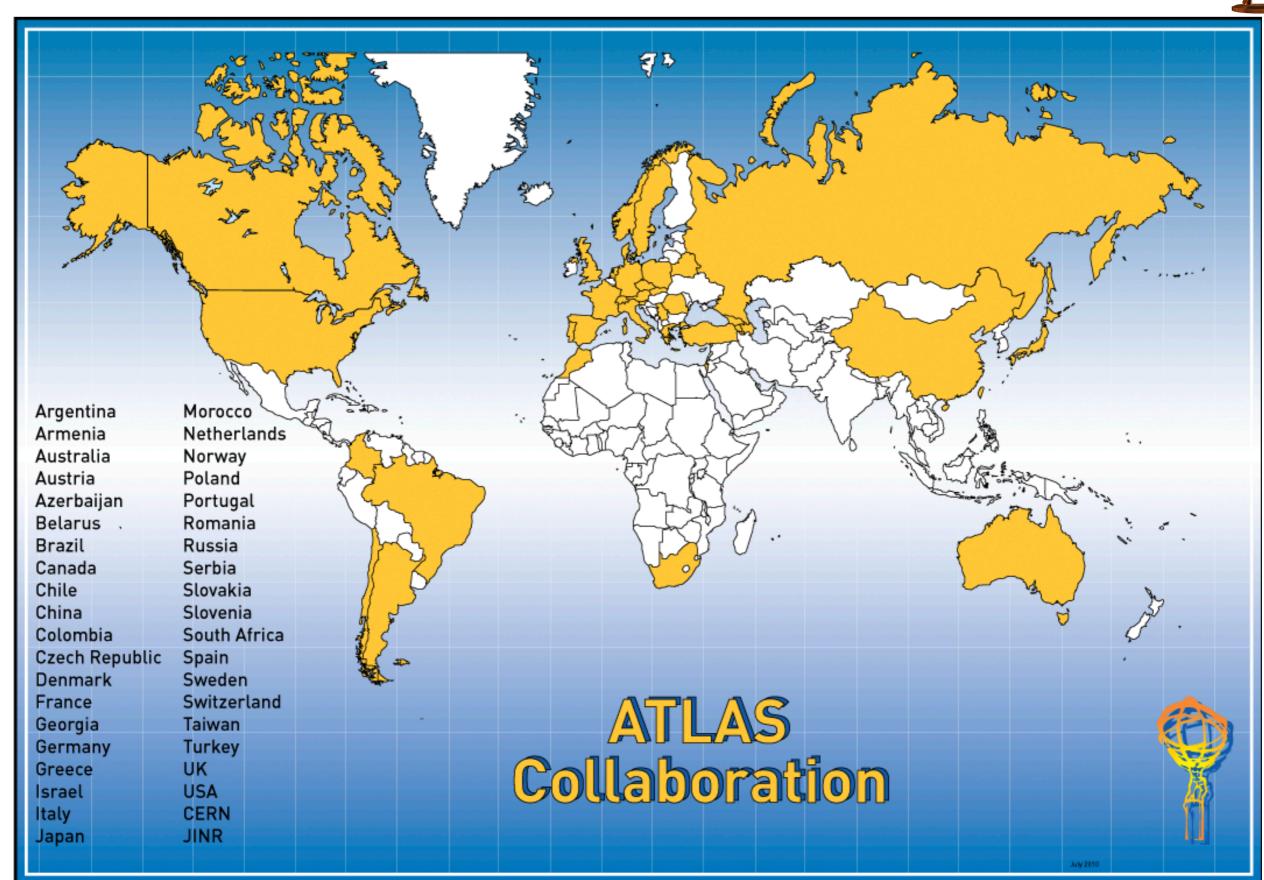






### ATLAS Collaboration

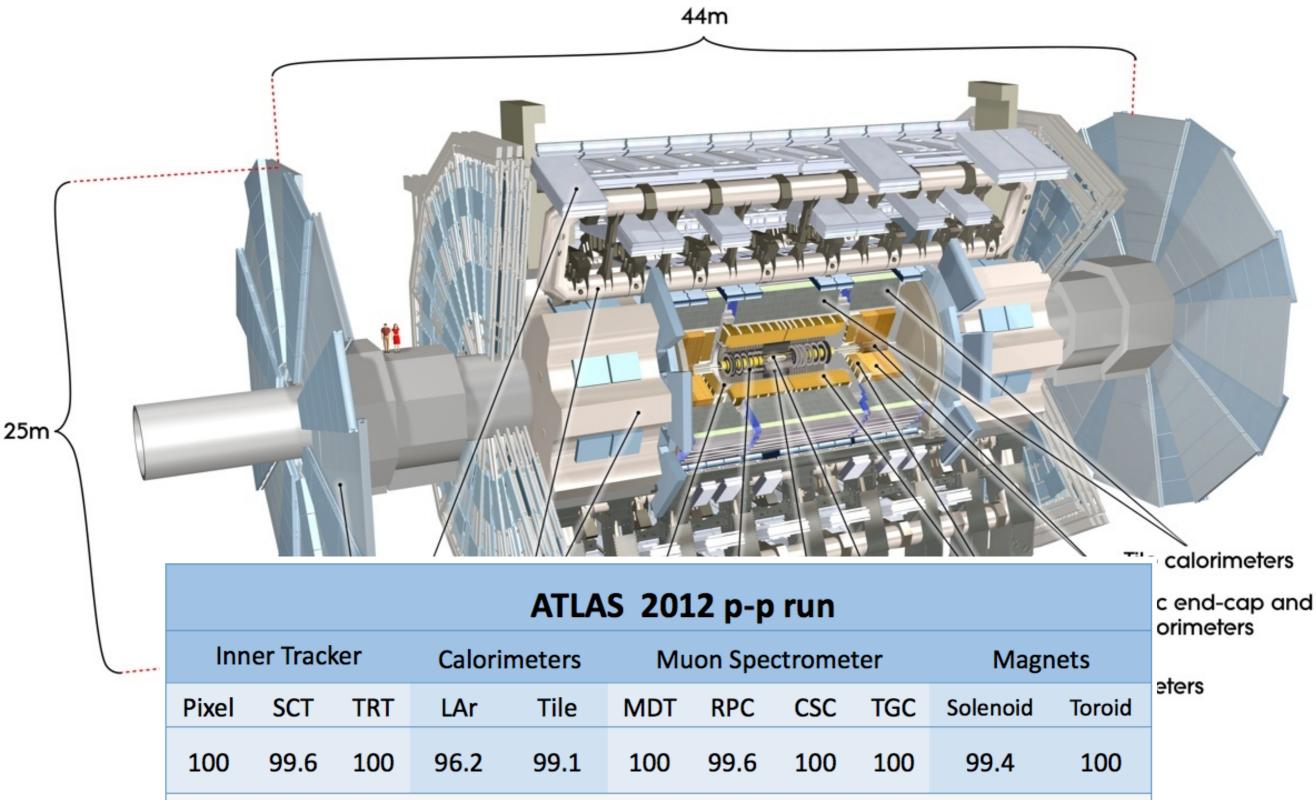






#### ATLAS Detector



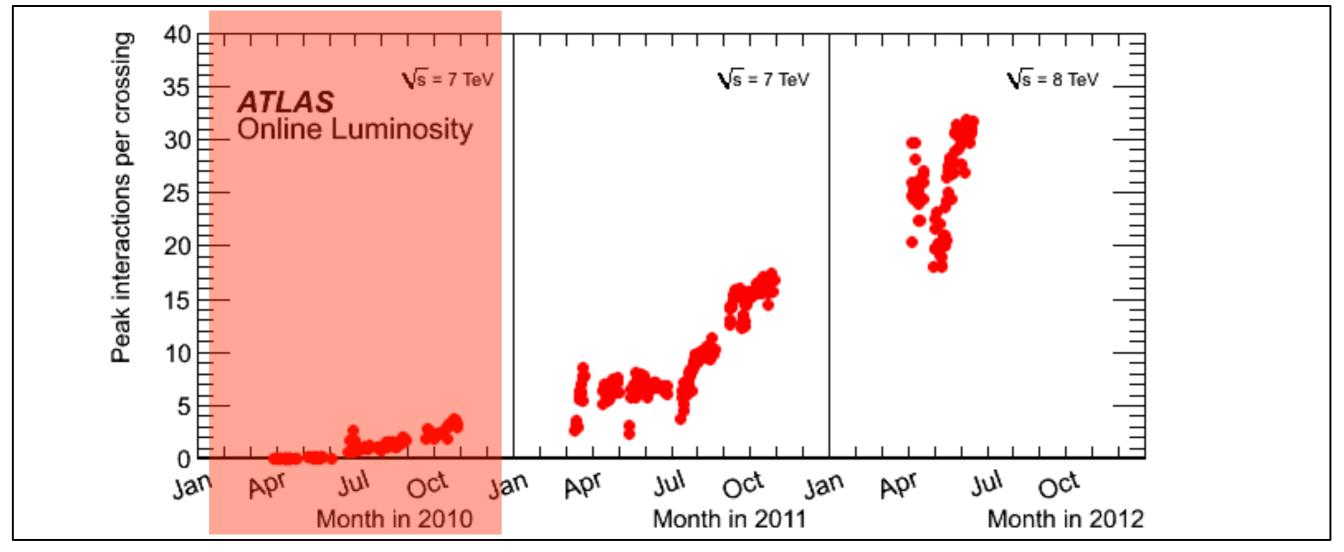


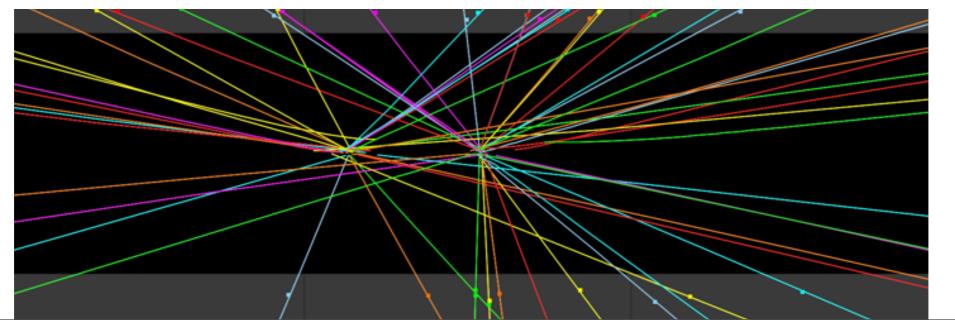
Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at Vs=8 TeV between April 4<sup>th</sup> and June 18<sup>th</sup> (in %) – corresponding to 6.3 fb<sup>-1</sup> of recorded data. The inefficiencies in the LAr calorimeter will partially be recovered in the future.



## Pileup Challenges



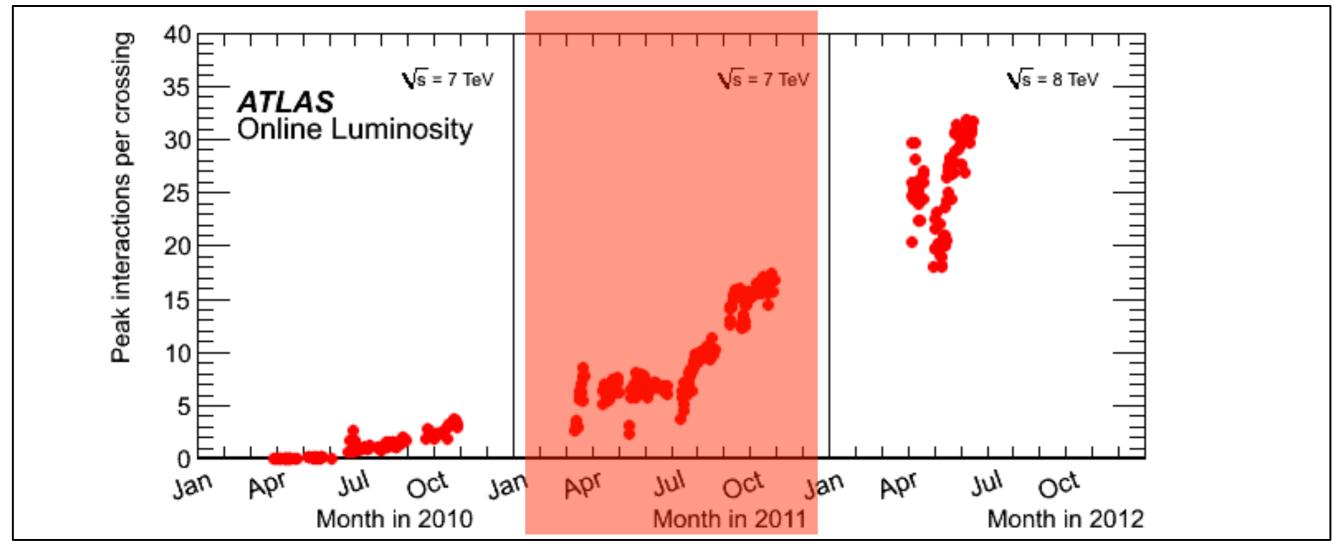


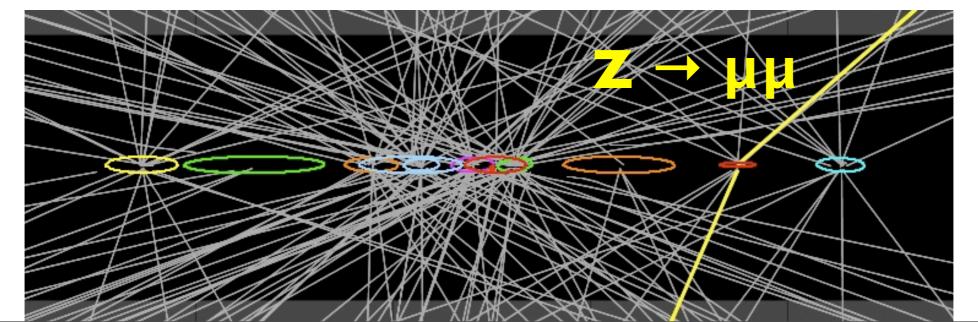




## Pileup Challenges



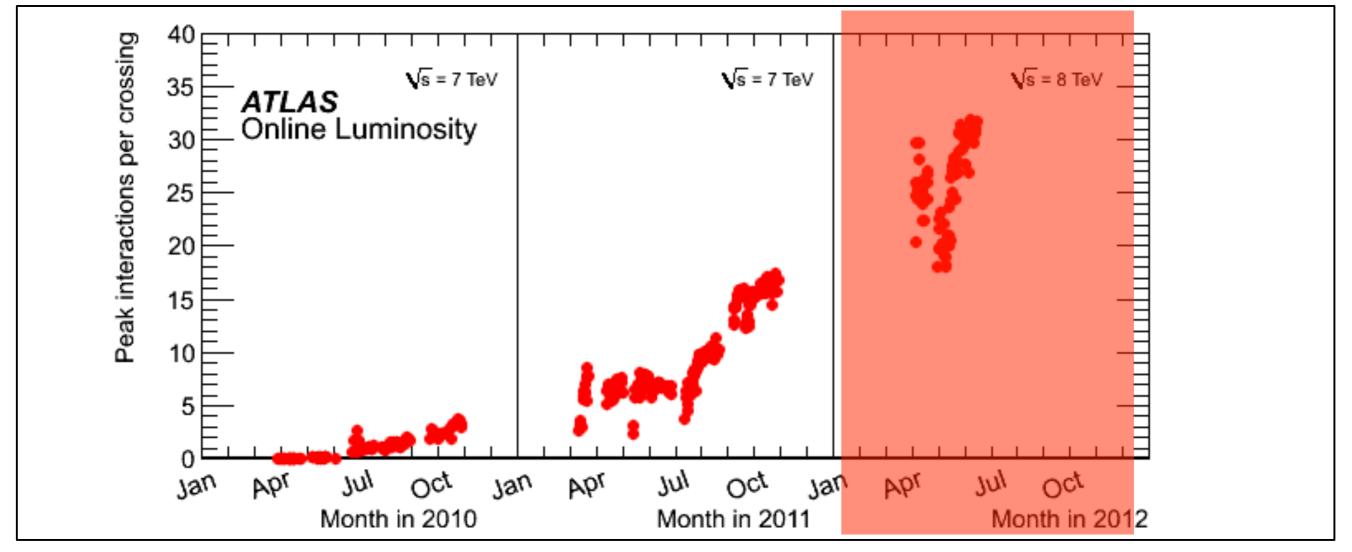


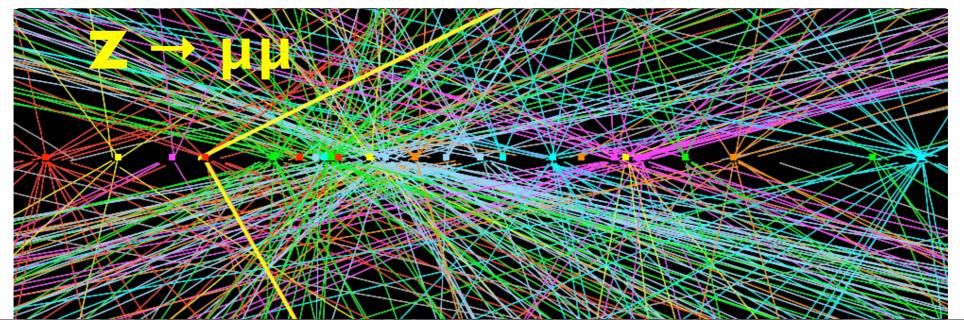




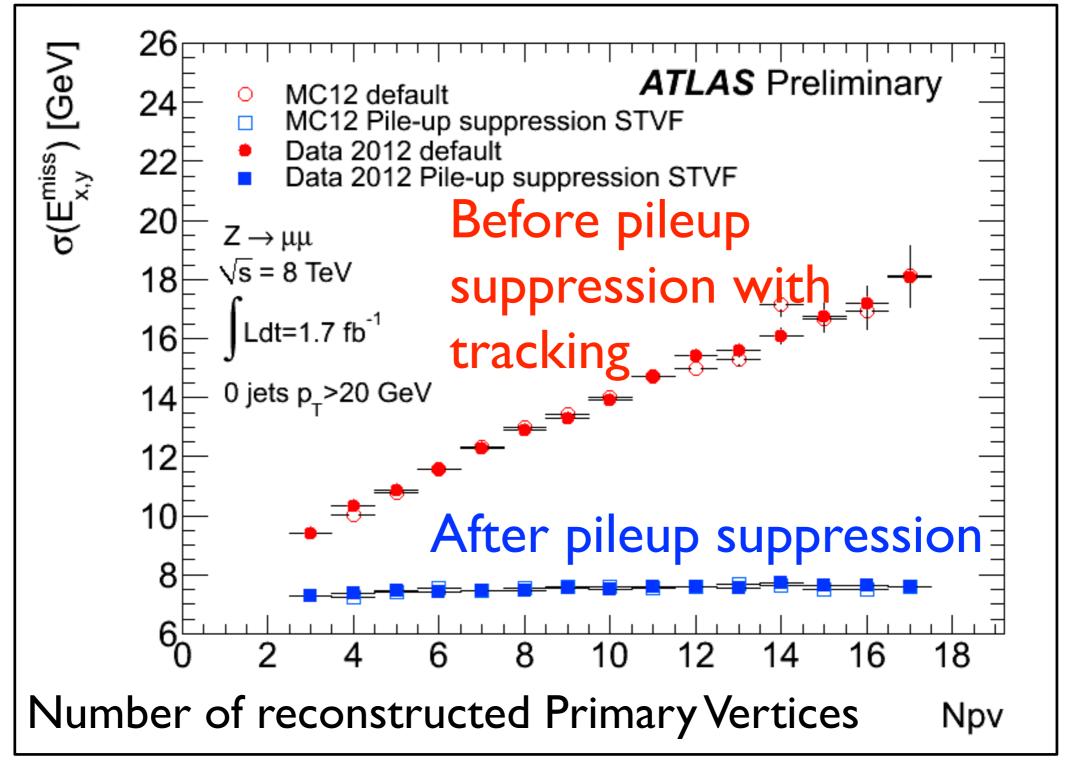
## Pileup Challenges









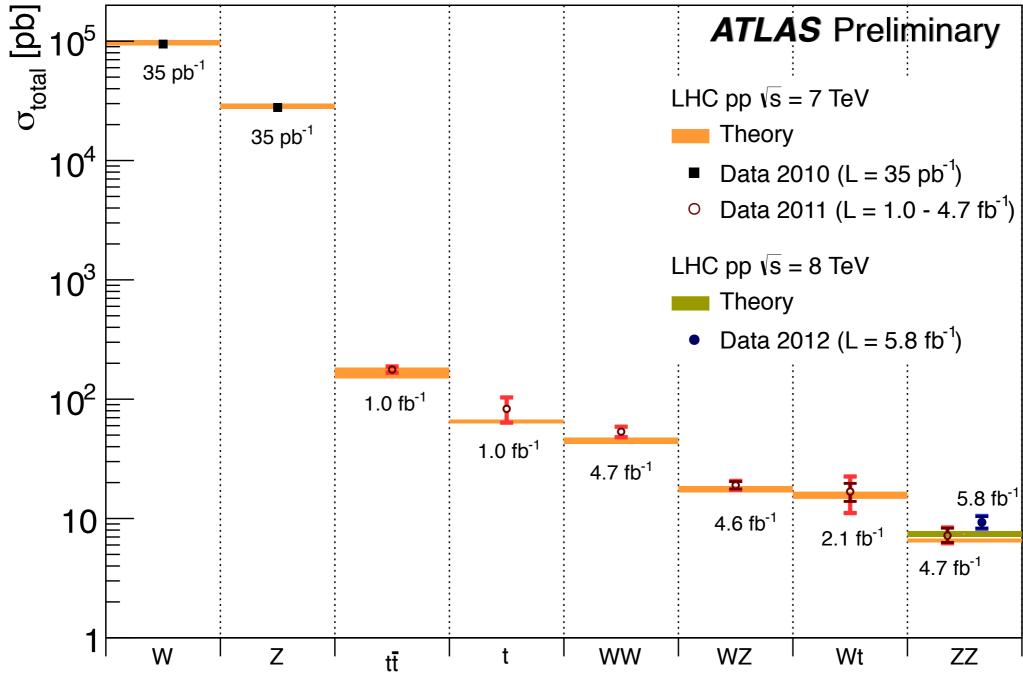


Understanding  $E_{\rm T}^{\rm miss}$  (highly sensitive to pileup) is critical for many searches.

#### COLUMBIA UNIVERSITY

### SM Cross Section Measurements

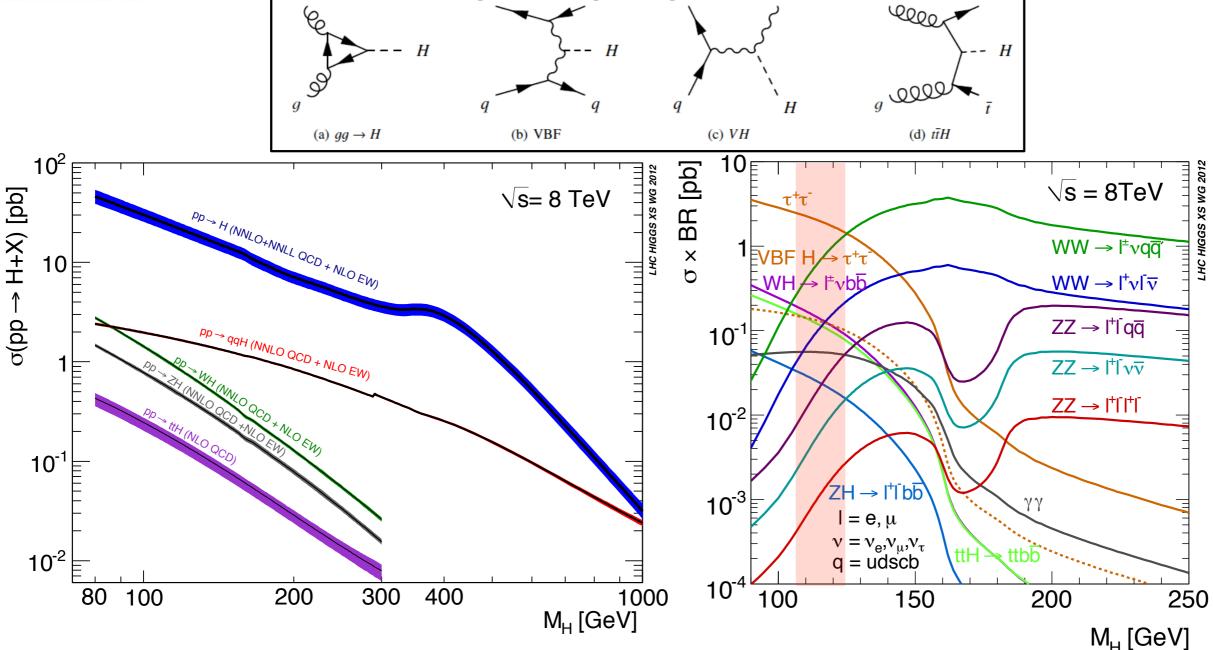




Electro-weak and top cross sections are fundamental on their own and for new physics searches (and discoveries). SM Higgs Production and Decay

W/Z 

W/Z



Signal modeled with Powheg+Pythia6 (7 TeV)/Pythia8 (8 TeV)+Photos for gg and VBF, Pythia for associated production.

SM Higgs cross sections increase ~1.3% from 7 to 8 TeV at m<sub>H</sub> ~125 GeV

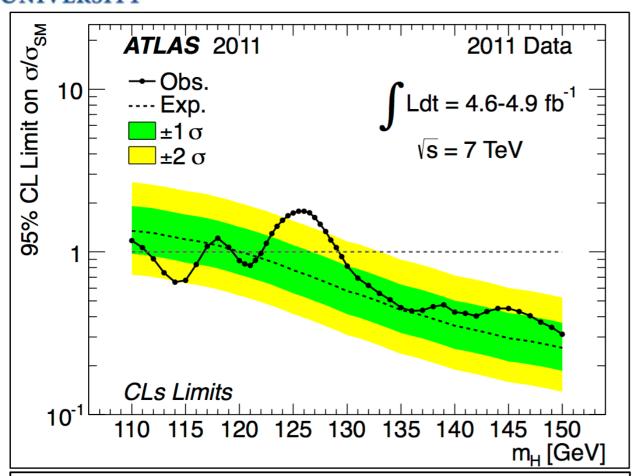
SM Higgs decay precisely predicted (except mass) at NLO and NNLO.

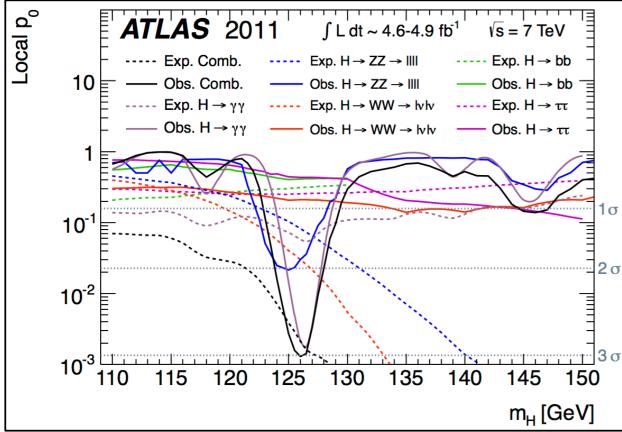
Most sensitive for I20 GeV <  $m_H$  < I30 GeV:  $\gamma\gamma$ ,  $\tau\tau$ ,  $ZZ^{(*)} \rightarrow 4I$ ,  $WW^{(*)} \rightarrow IVIV$ ,  $W/Zb\overline{b}$ 



#### Hints from 2011







#### Combination of 12 channels:

- $H \rightarrow \gamma \gamma$ ,
- W/ZH → W/Z bb
- H → TT
- H → ZZ(\*) → 4I
- H → WW(\*) → IVIV
- H → ZZ → IIqq
- $\bullet$  H  $\rightarrow$  ZZ  $\rightarrow$  II $\vee$  $\vee$
- $H \rightarrow WW \rightarrow Ivqq$

## 2.9 $\sigma$ excess for $m_H = 126$ GeV



### Improvements since 2011



- With the 2011 data we improved our detector understanding, alignment and calibration and pileup understanding along with improvements in  $e/\gamma/\mu$  ID efficiency.
- Early 2012: Focus on 2 channels:  $H \rightarrow \gamma \gamma$  and  $H \rightarrow ZZ^{(*)}$ .  $H \rightarrow WW^{(*)}$  is also sensitive, but it is more difficult to see the expected broad excess in the  $M_T$  distribution.
- Re-optimize analysis for high pileup and low m<sub>H</sub> using MC and 2011 data.
- Fix selections and techniques before looking at 2012 data.



## SM $H \rightarrow \gamma \gamma$ - Analysis



Relatively simple final state of two photons:

 $\gamma_1 p_T > 40 \text{ GeV}, \gamma_2 p_T > 30 \text{ GeV}$ 

Identified using calorimeters clusters and conversions vertices in tracker.

Split into 10 categories based on  $\eta$  and un/converted,  $p_T(\gamma\gamma)$ , and (new) 2 jet VBF category to improve sensitivity.

#### Improved yy mass resolution:

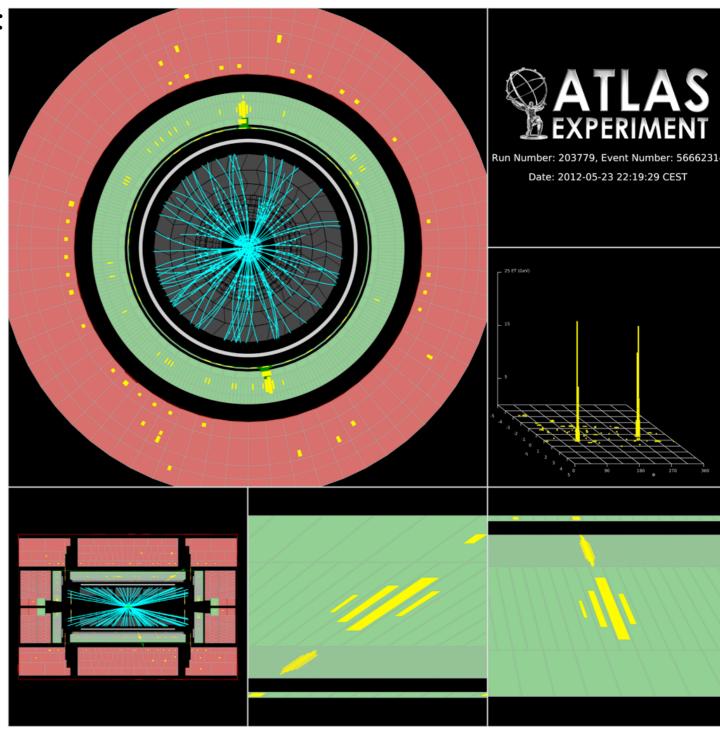
Search for signal over SM  $\gamma\gamma$  irreducible background: better resolution increases sensitivity.

**Photon ID**: Reject jet  $\rightarrow \pi^{\circ} \rightarrow$  fake  $\gamma$  background ( $10^4$  - $10^7$  times larger cross section) with improved photon ID.

Expect (with  $10 \text{ fb}^{-1} \text{ m}_{H}=126 \text{ GeV}$ ):

~170 signal events

~6340 background events





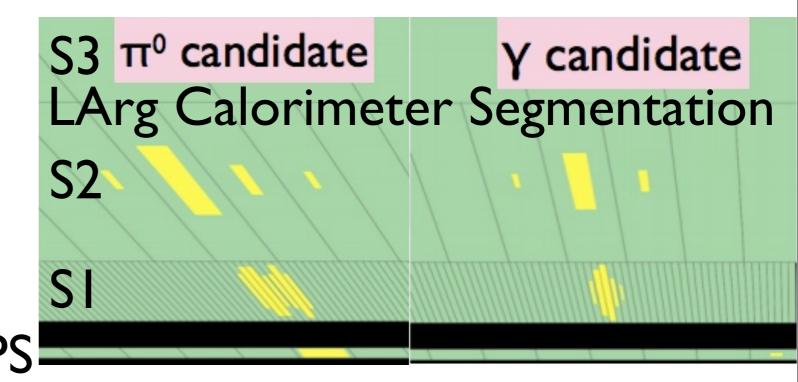
SM H→yy - ID and Reconstruction

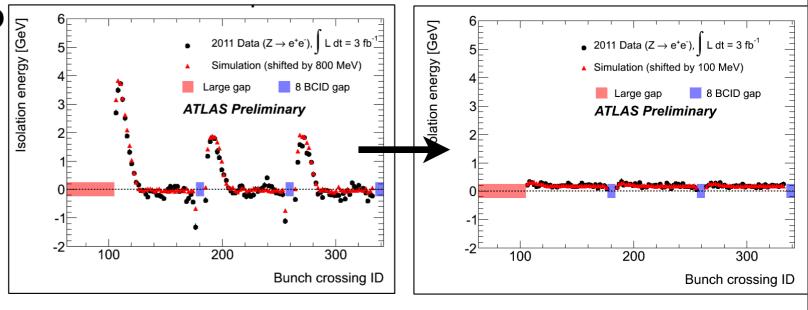
Suppress jet background using shower shape variables from first (finely segmented) calorimeter layer.

Neural net 2011 data, cut based 2012

Asolation determined using clusters with  $\Delta R=0.5$ . Pileup rected for ambient avent.

Subtraction improved to remove dependence on bunch position.



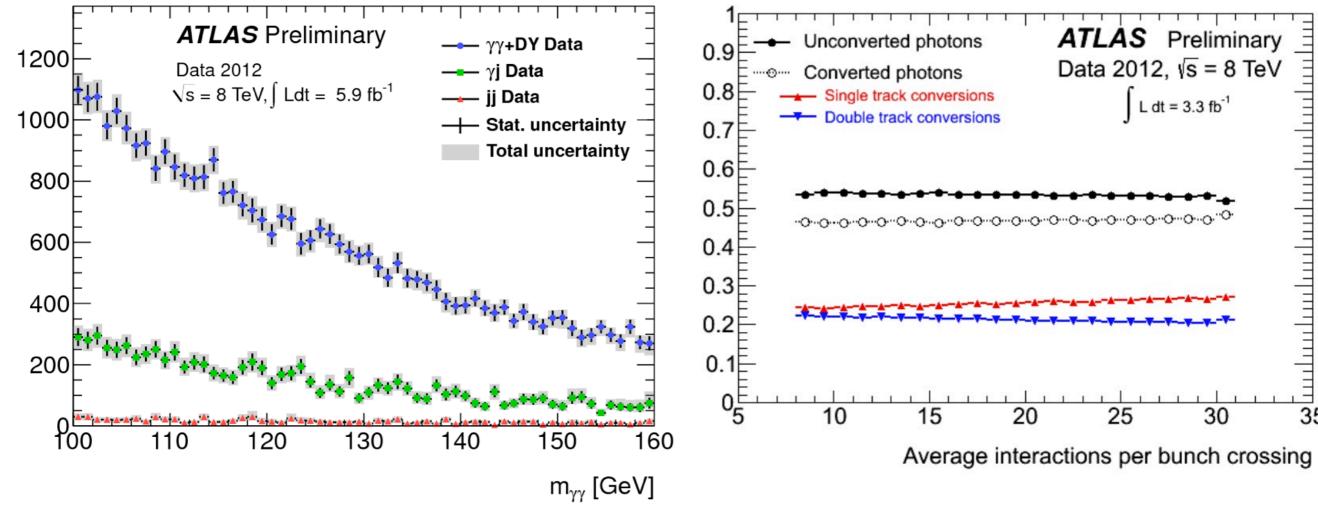




≣vents / GeV

## SM H→γγ - Event composition





After selection background contains 75-80% SM  $\gamma\gamma$  20-25%  $\gamma$ -jet, jet-jet.

Converted/Unconverted photons stable vs pileup.



### SM H-YY - Mass Resolution



$$m^2_{YY} = 2 \cdot E_1 E_2 \cdot (1 - \cos \alpha)$$

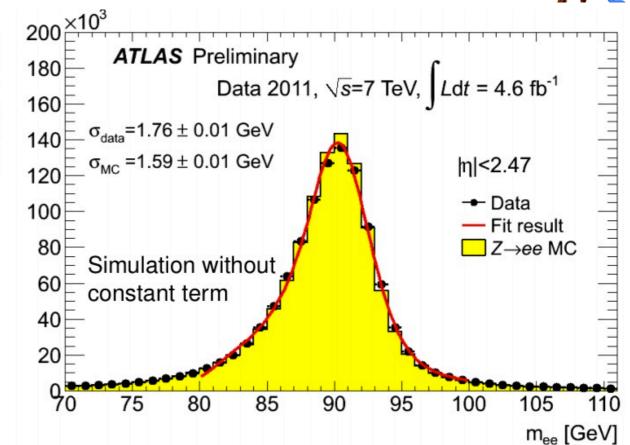
Energy calibration improved with corrections derived from  $Z\rightarrow ee, W\rightarrow ev$  and  $J/\Psi\rightarrow ee$ .

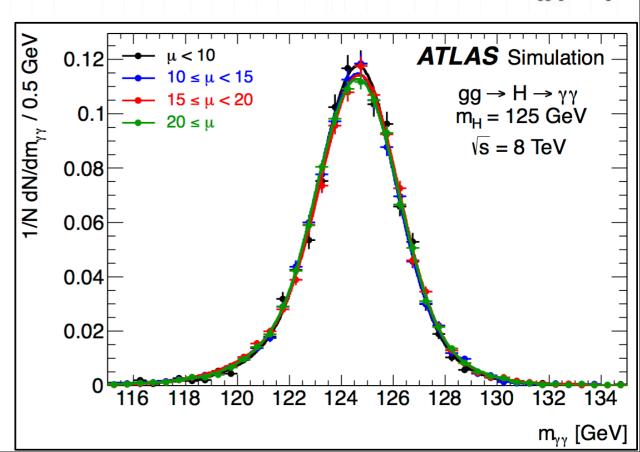
Energy scale at m<sub>Z</sub> know to 0.5%, linear to better than 1%.

Resolution constant term ~1%.

Calibration transported from ee to  $\gamma\gamma$  using MC.

Mass resolution for 125 GeV signal ~1.6 GeV.







### YY - Mass Resolution



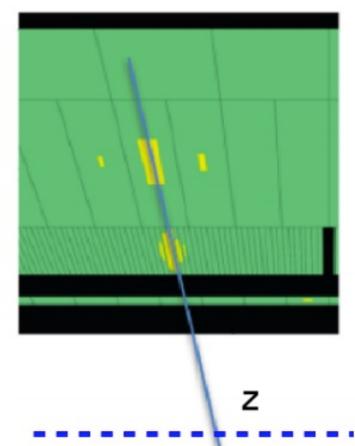
$$m^2_{YY} = 2 \cdot E_1 E_2 \cdot (1 - \cos \alpha)$$

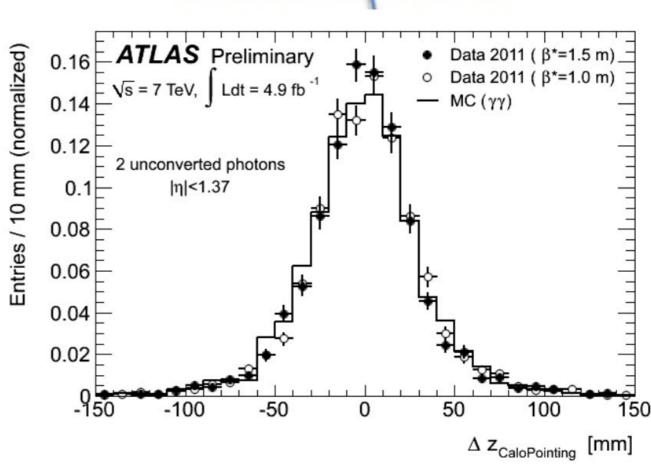
Photon angle measurement based on photon pointing.

Photon direction determined using longitudinal segmentation of calorimeter.

Photon pointing reduces vertex uncertainty from 5-6 cm to 1.5 cm, sufficient for  $m_{\gamma\gamma}$ .

A likelihood combining tracking information with calorimeter pointing is required for jet selection in VBF category.

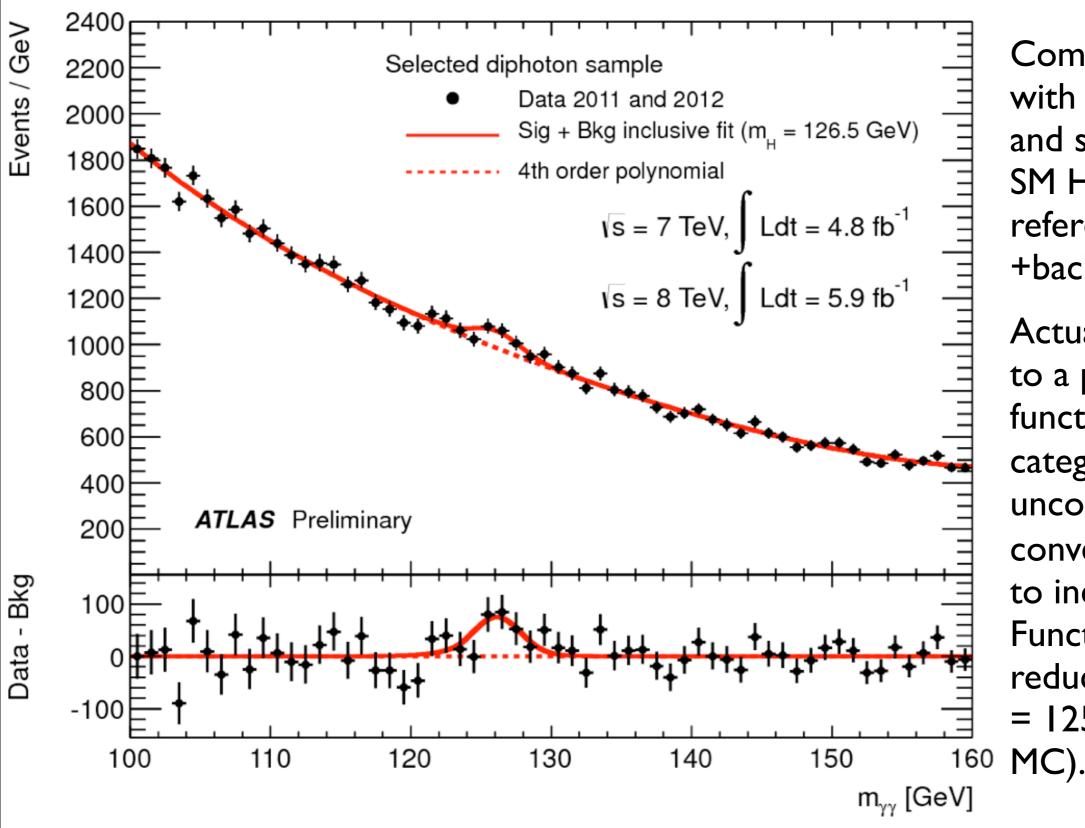






## m(yy) Distribution



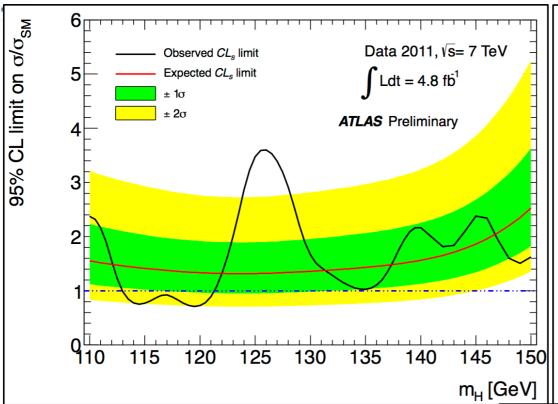


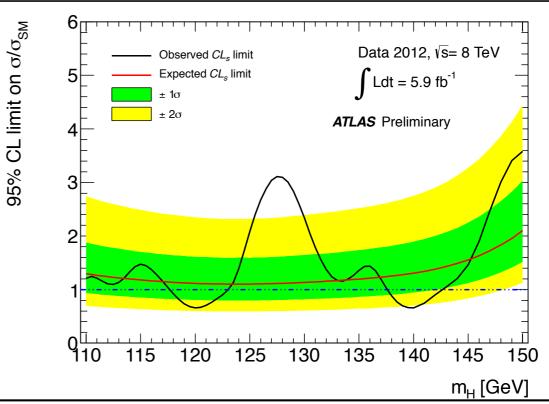
Combined distribution with background fit and signal (126.5 GeV SM Higgs for reference) +background.

Actual background fit to a polynomial function is done within categories of  $\eta$ , unconverted/
converted and  $\gamma\gamma$  pt to increase sensitivity. Function chosen to reduce the bias for mH = 125 GeV (studied in MC)



### SM $H \rightarrow \gamma \gamma$ - Exclusion

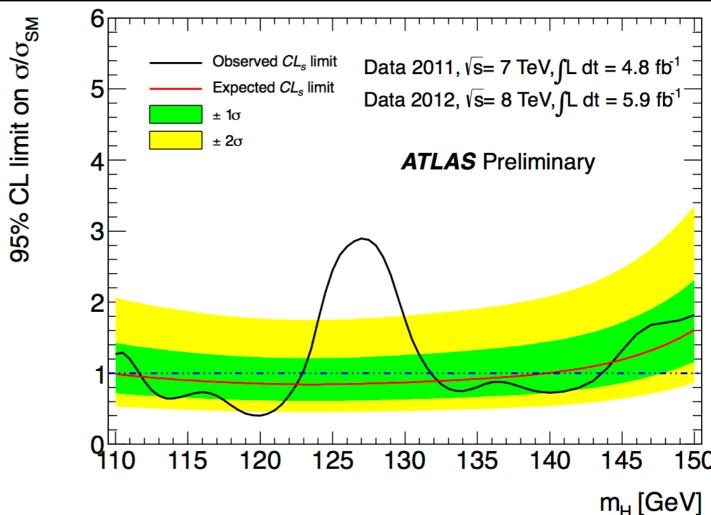




Expected exclusion from 110 - 140 GeV.

Actual exclusion at 95% from 112 - 122.5 GeV and 132 - 143 GeV.

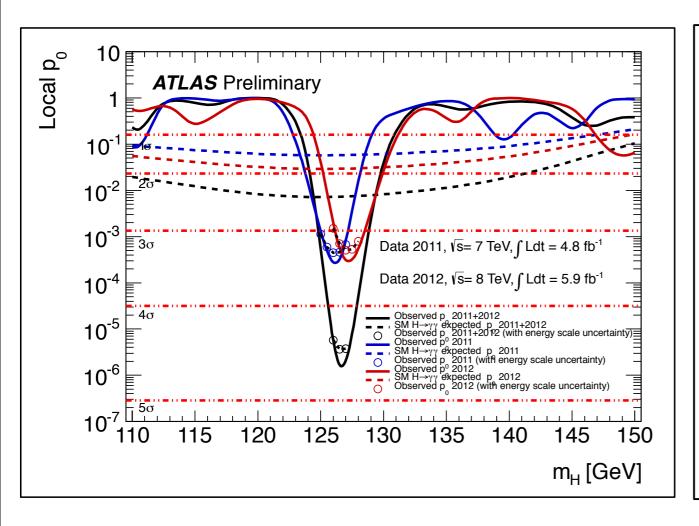
Largest deviation from background only at 126.5 GeV.

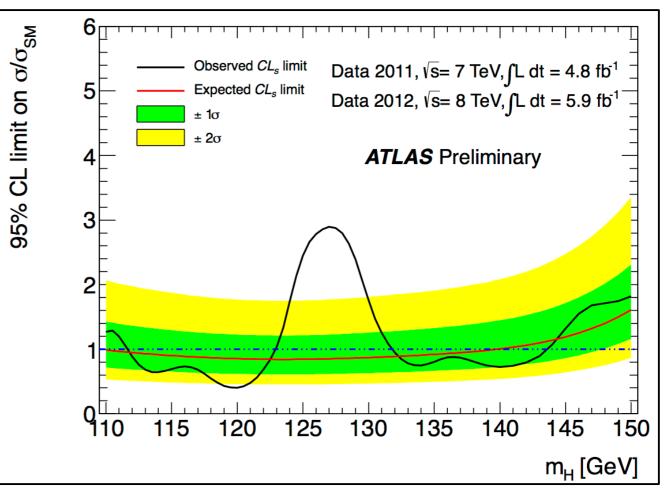




## SM H→ yy Significance







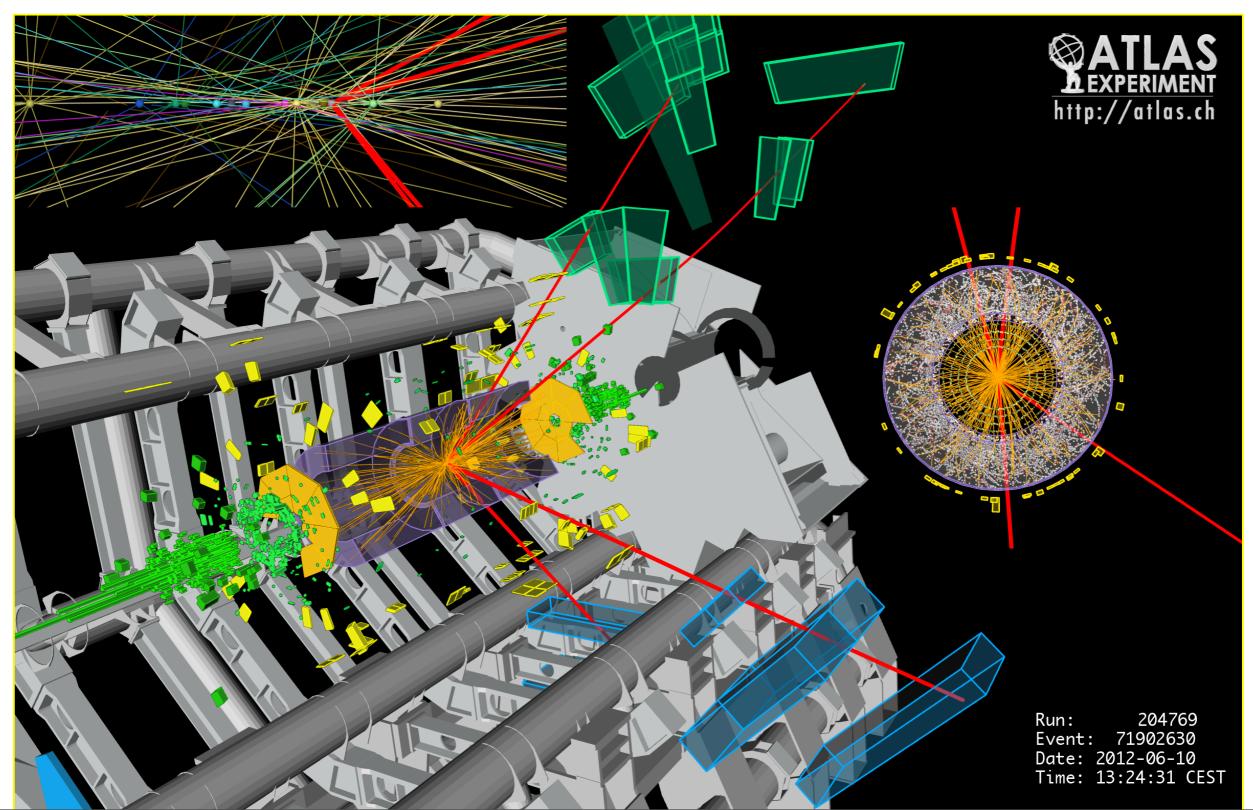
# Combined local significance with 2011 and 2012 data of $4.5\sigma$ .

Expected for SM Higgs at m<sub>H</sub>=126.5 GeV is  $2.4\sigma$ )





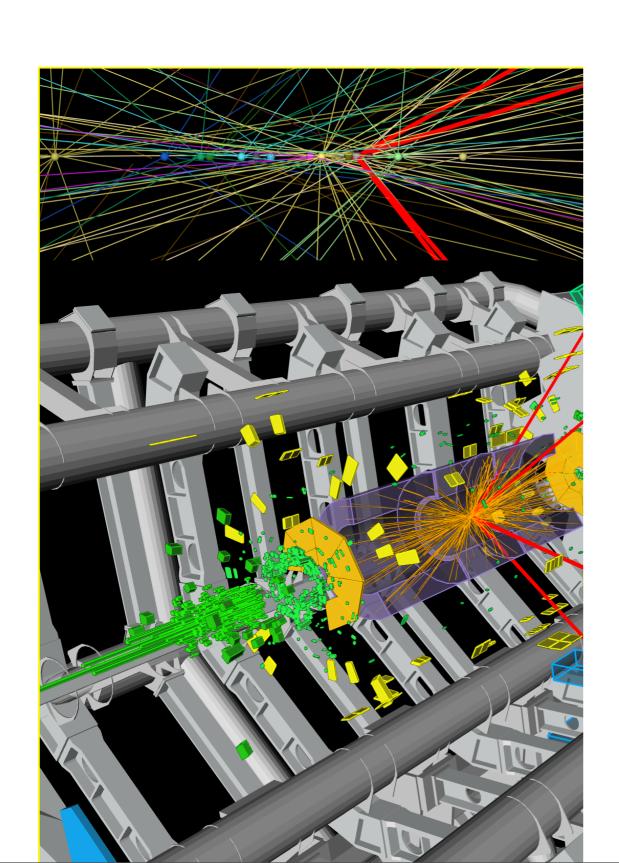
### $4 \mu \text{ event } m_{4\mu} = 125.1 \text{ GeV}$ $m_{12} = 86.3 \text{ GeV}, m_{23} = 31.6 \text{ GeV}$





## SM $H \rightarrow ZZ^{(*)}$ Analysis





Relatively simple final state: 4 leptons (e/ $\mu$ )

Low rate but the final state is pure (S/B~I) and can be completely reconstructed.

#### Select:

Lepton  $p_T^{1,2,3,4} > (20, 15, 10, 7/6 e/\mu)$  GeV,  $50 < m(II)_{12} < 106$  GeV,  $m(II)_{23} > 17.5 - 50$  GeV (vs. m<sub>H</sub>) impact parameter cut on 2 soft leptons.

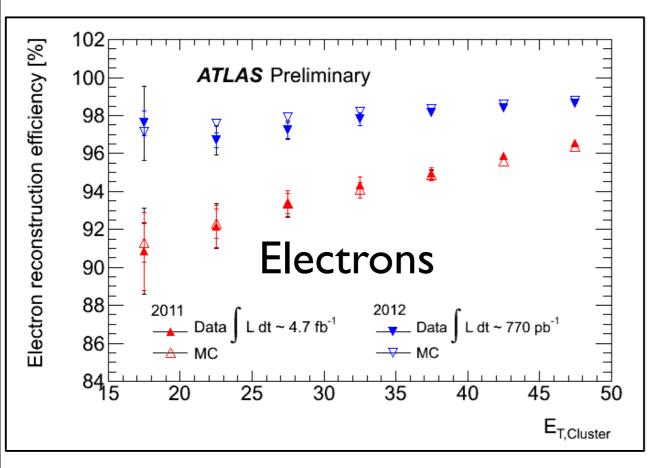
Acceptance and efficiency: Need to find leptons at low p<sub>T</sub>.

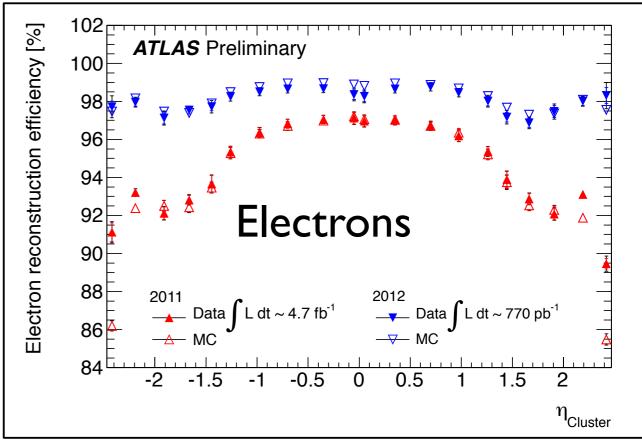
**4l mass resolution**: Observe signal over SM ZZ<sup>(\*)</sup> irreducible background. Better resolution increases sensitivity.

**Low Mass Backgrounds**: Cannot rely only on MC.



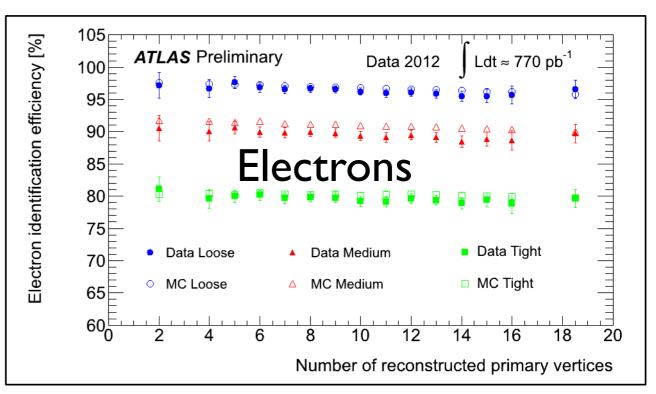
## SM $H \rightarrow ZZ^{(*)}$ e/ $\mu$ Reconstruction





**Electrons**: Improved reconstruction efficiency at low p<sub>T</sub>, ID efficiency flat vs. pileup.

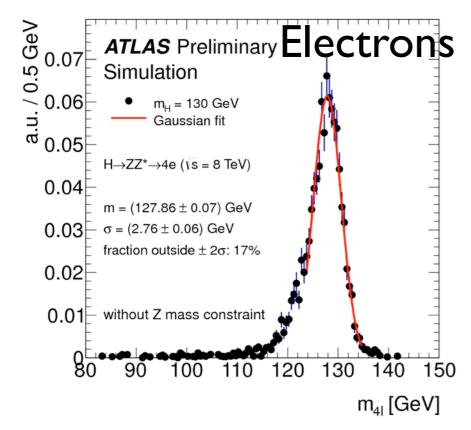
Muons: Reconstructed down to 6 GeV, efficiency flat in  $\eta$  and vs pileup.

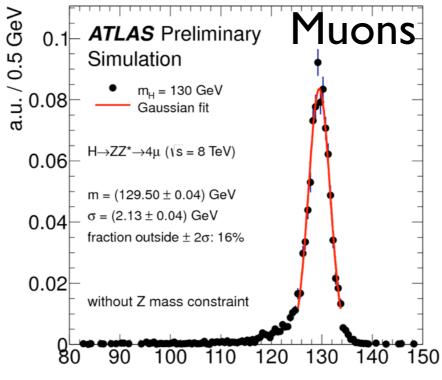




## SM $H \rightarrow ZZ^{(*)}$ Mass Resolution

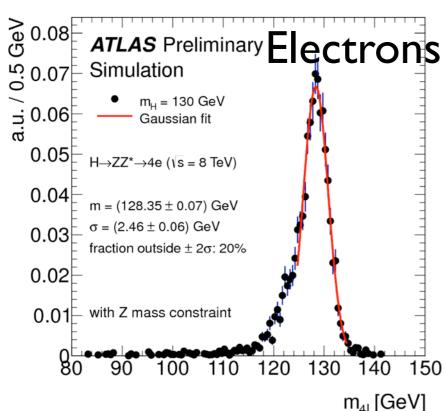


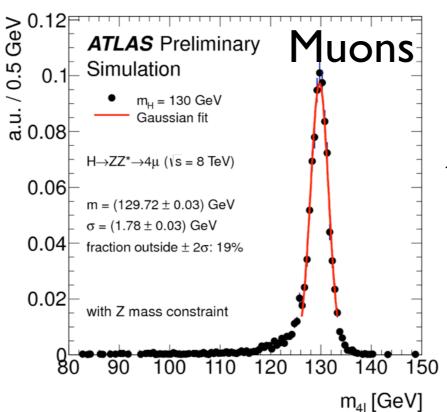




m<sub>41</sub> [GeV]

Narrow resolution critical for finding peak on smooth background.



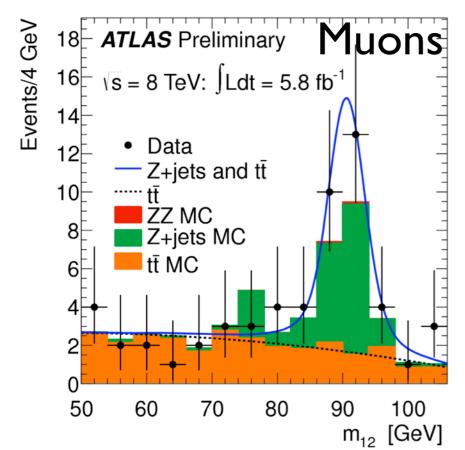


Resolution improved  $\sim 10\text{-}15\%$  by constraining  $m_{12}$  to  $m_Z$  (and  $m_{34}$  for  $m_H > 190$  GeV).



## SM $H \rightarrow ZZ^{(*)}$ Backgrounds

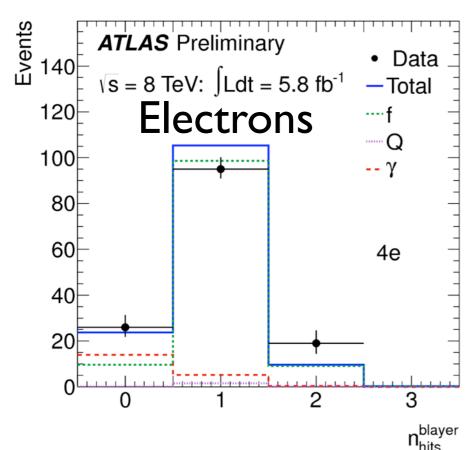


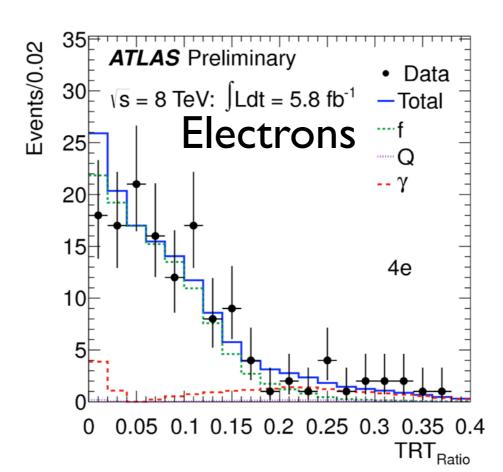


#### **Muons:**

Background dominated by ZZ(\*) with Zqq/bb + t t important at low  $m_H$ .

Strategy is to relax isolation and impact parameter requirements and then fit for the yields in this background enriched region, and finally to extrapolate to signal region.





**Electrons**: Background of light jets faking an electron (f), photon conversions (γ) and heavy quark semileptonic decays (Q) important low m<sub>H</sub>.

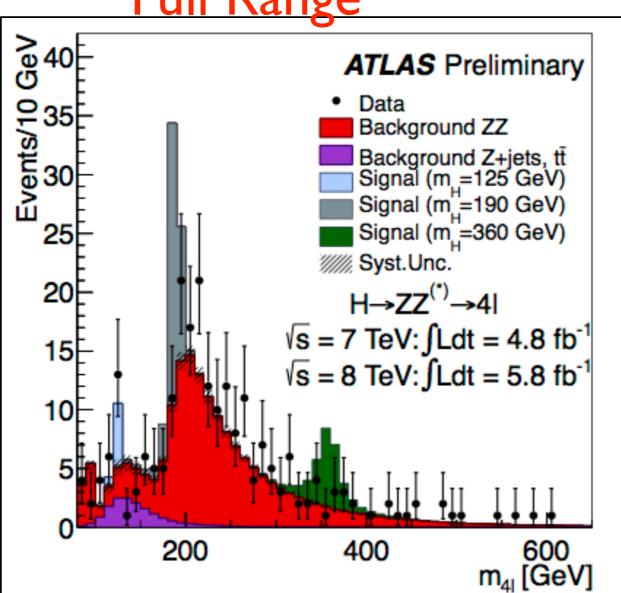
Again, relax selection and fit yields using tracking and calorimeter variables. Extrapolate to signal region.



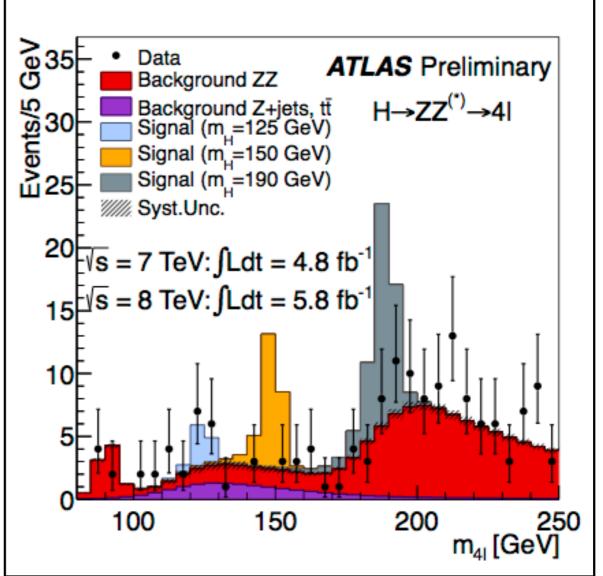
## SM $H \rightarrow ZZ^{(*)}$ Final Selection



Full Range







#### Events at 125 ± 5 GeV:

Dataset	2011	2012	Combined
Background	2 ± 0.3	3 ± 0.4	5.1 ± 0.8
Signal	2 ± 0.3	3 ± 0.5	5.3 ± 0.8
Observed	4	9	13

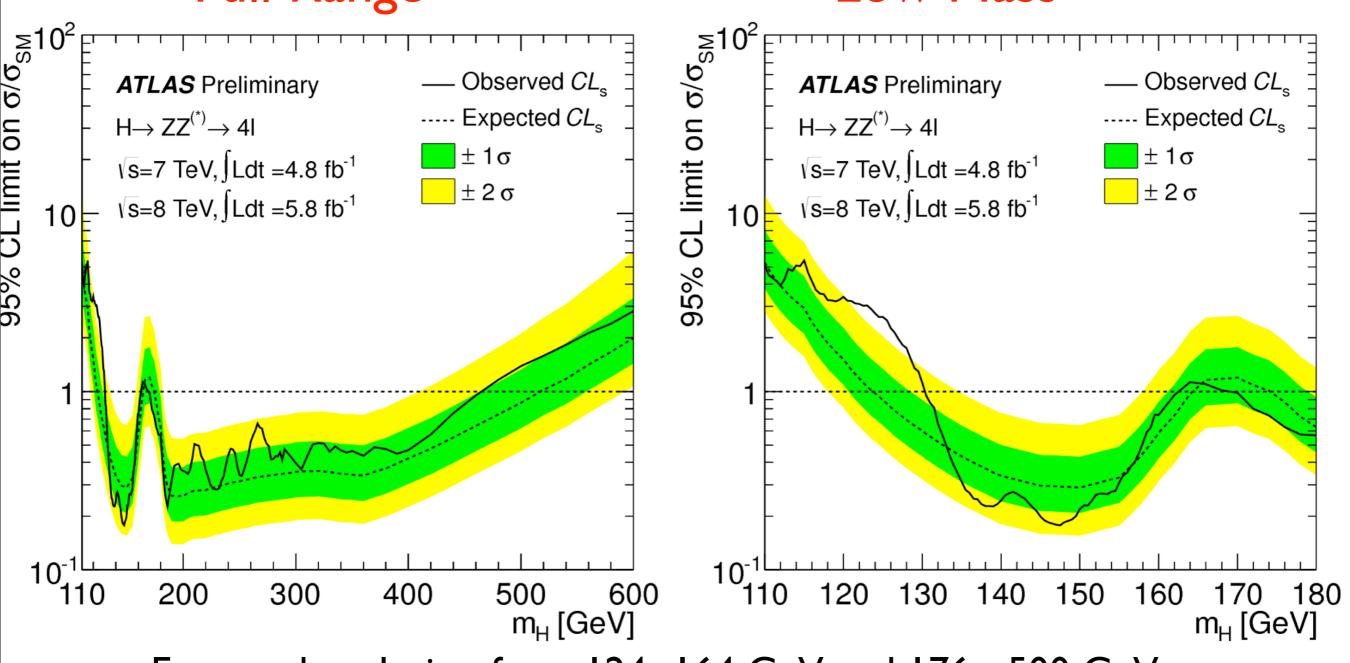


## SM $H \rightarrow ZZ^{(*)}$ Final Selection



#### Full Range





Expected exclusion from 124-164 GeV and 176 - 500 GeV.

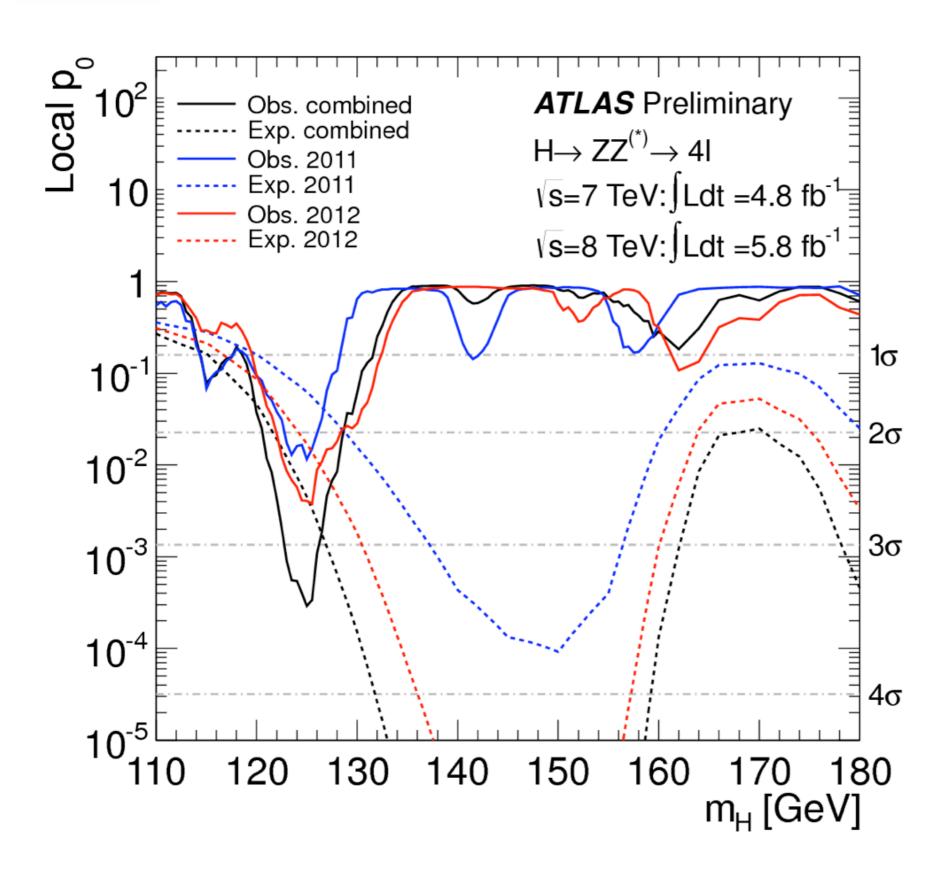
Actual exclusion at 95% from 131-162 GeV and 170-460 GeV.

Around 126 GeV there is no exclusion.



## SM $H \rightarrow ZZ^{(*)}$ Significance





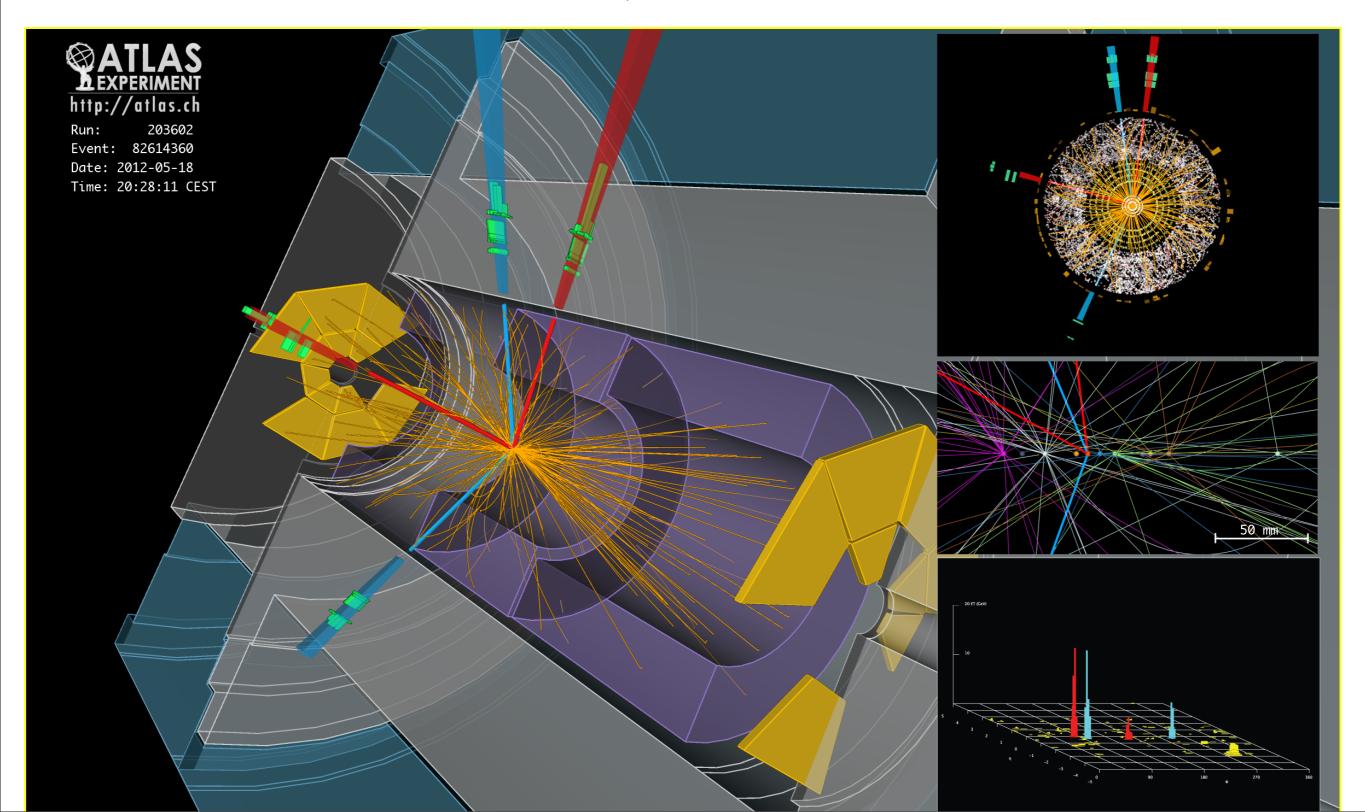
Combined local significance with 2011 and 2012 data of 3.40 at 125 GeV.

Expected for SM Higgs at  $m_H=125$  GeV is  $2.6\sigma$ )





#### 4e event $m_{4e} = 124.6 \text{ GeV}$ $m_{12} = 70.6 \text{ GeV}, m_{23} = 44.7 \text{ GeV}$

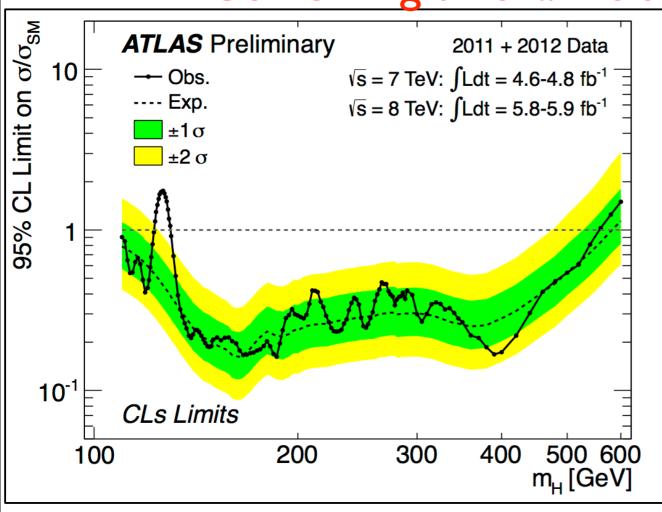


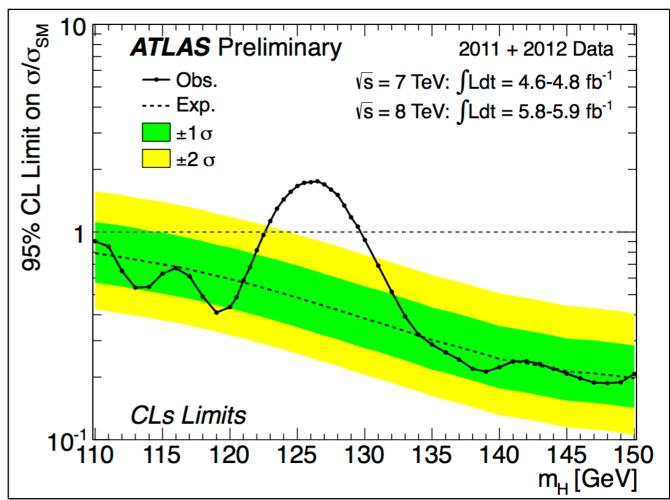


### Channel Combination



#### Combining all channels from 2012 and 2011





Expected exclusion from 110 - 575 GeV.

Actual exclusion at 95% from 110.0-122.7 GeV and 129.7-557 GeV.

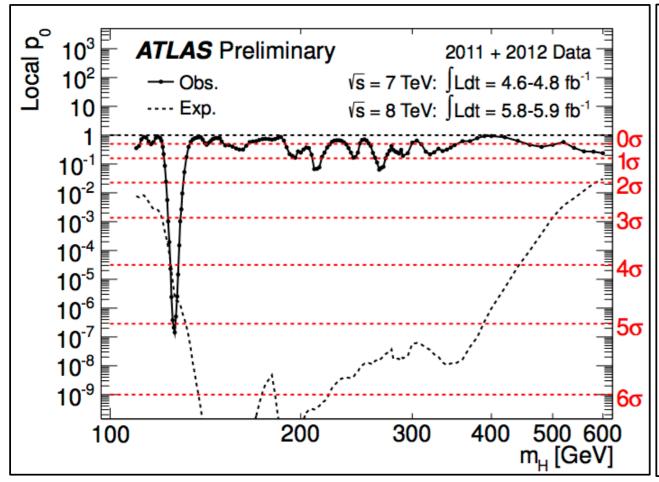
Actual exclusion at 99% from 112.6-121.7 GeV and 129.7-556 GeV.

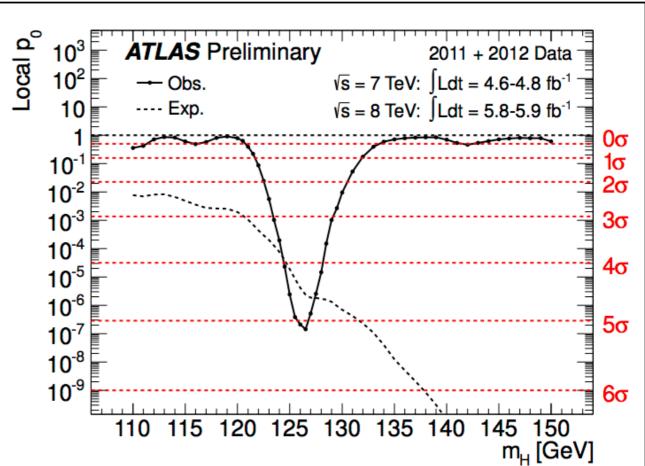
Around 126 GeV there is no exclusion.



#### Channel Combination







Excellent agreement across entire mass range ( $\pm 2\sigma$ ) with background only hypothesis, except close to 126 GeV.

#### Local excess of 5.0σ at 126.5 GeV

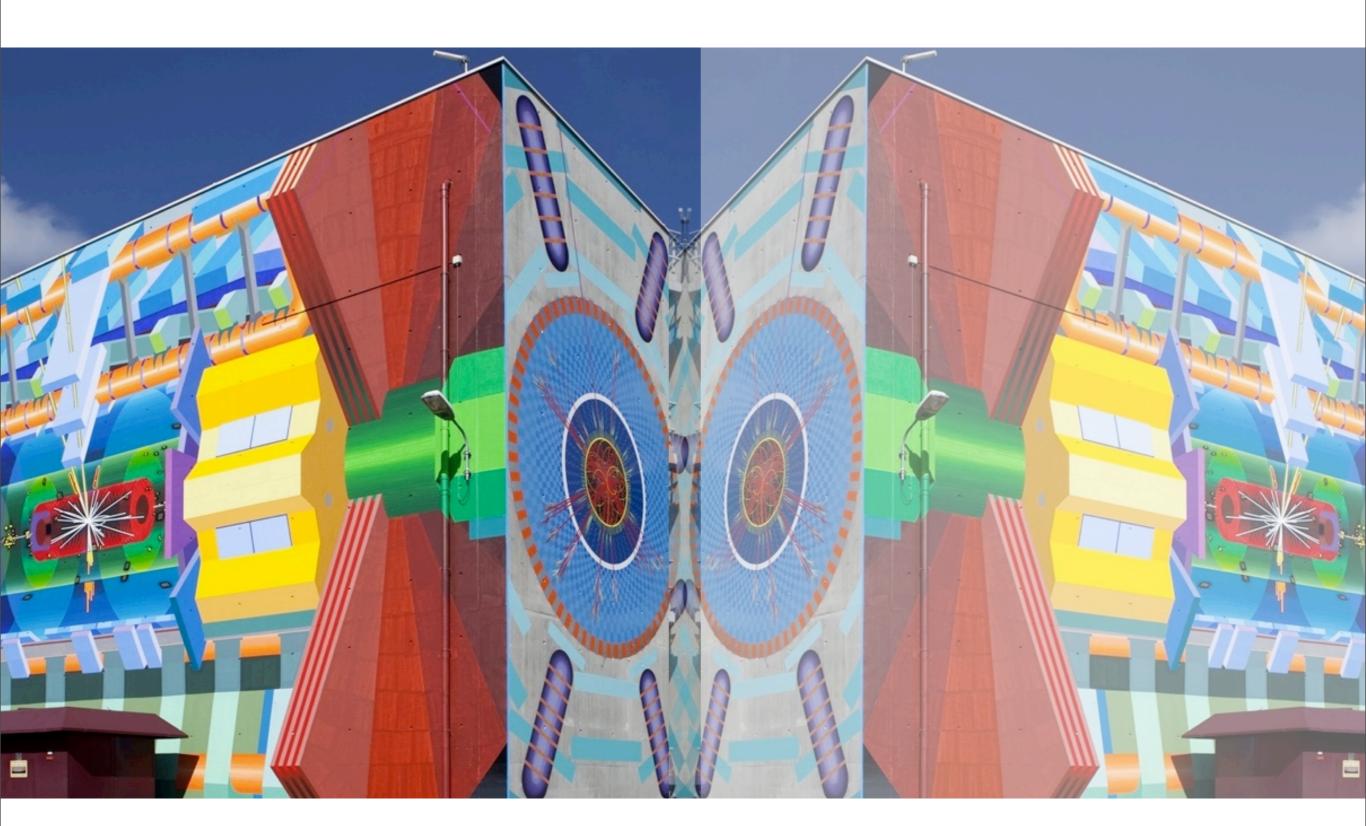
Expected from SM Higgs  $m_H = 126.5 \text{ GeV} = 4.6\sigma$ 

Global significance: 4.1 to  $4.3\sigma$  for LEE over 110-600 GeV or 110-150 GeV



## **SUSY Searches**

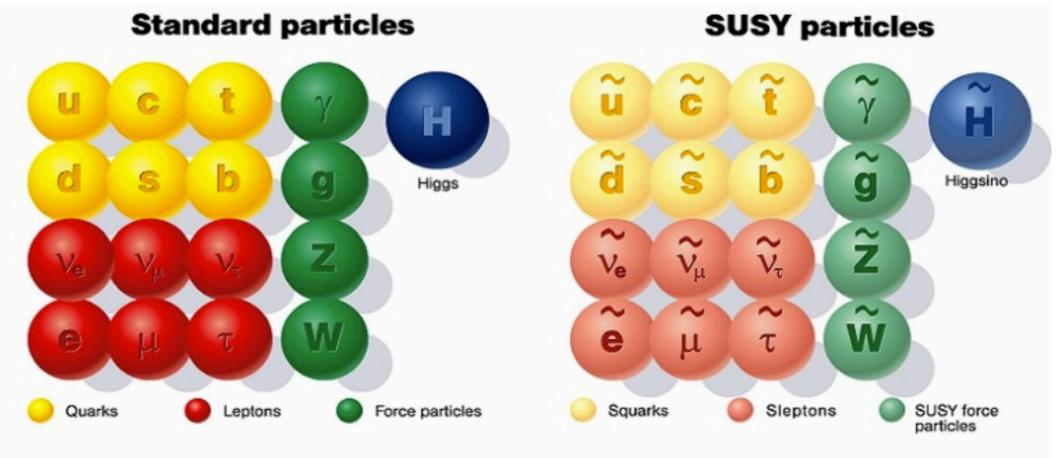






### SUSY



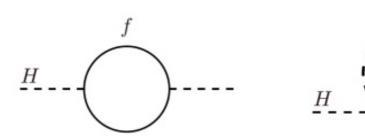


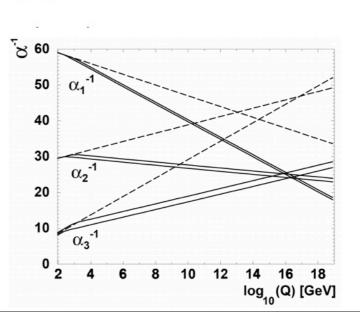
#### **Provides:**

Solution to gauge hierarchy

Gauge coupling unification

Cold dark matter candidate





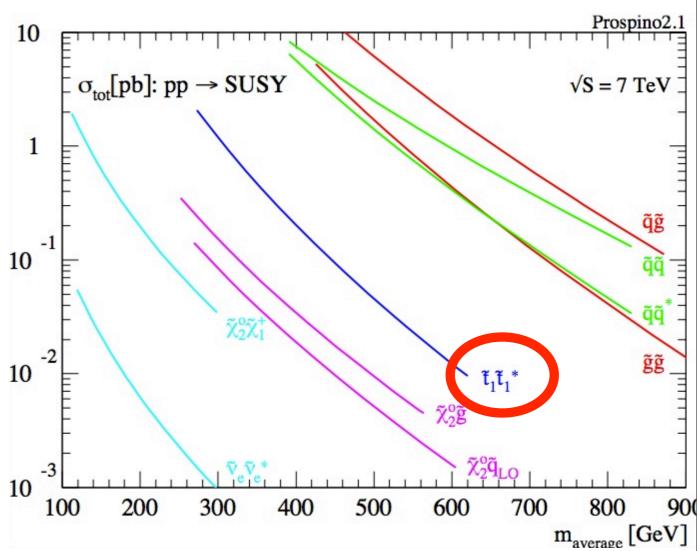


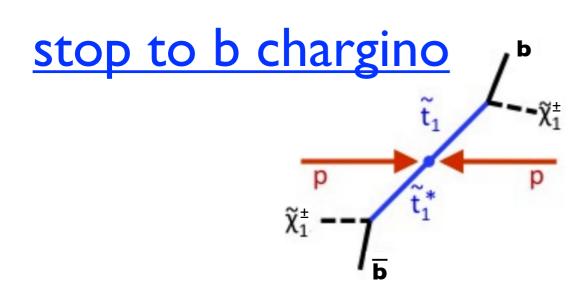
## Hunting the Top Squark

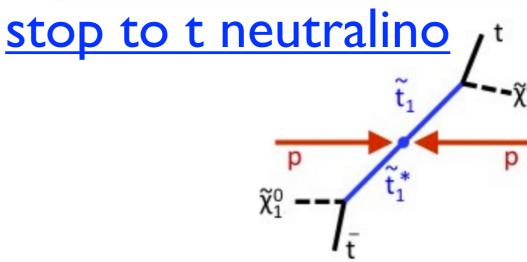


#### Where next?

- a priori squarks could have different masses.
- A light 3rd generation is well motivated in SUSY.
- Focus on dedicated stop searches at 7 TeV with ~5fb<sup>-1</sup>.
   In order of increasing masses.









### Direct light stop search - 2 lepton

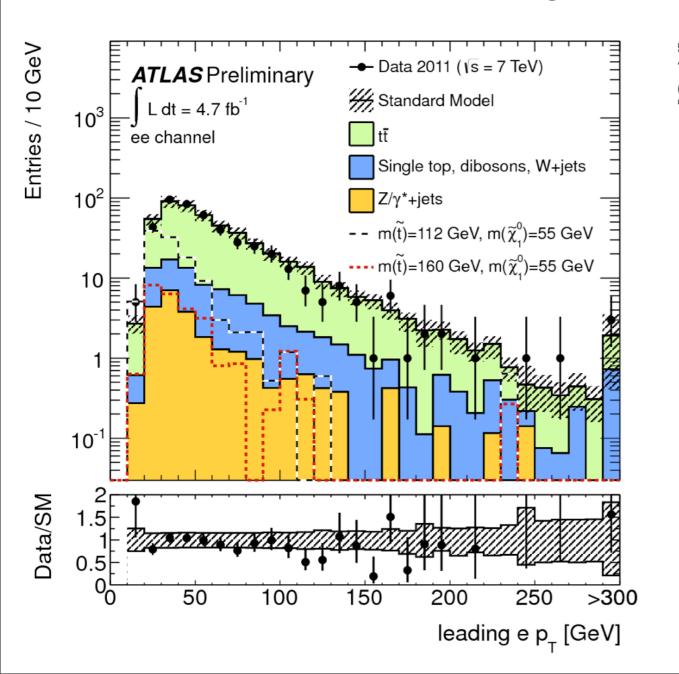


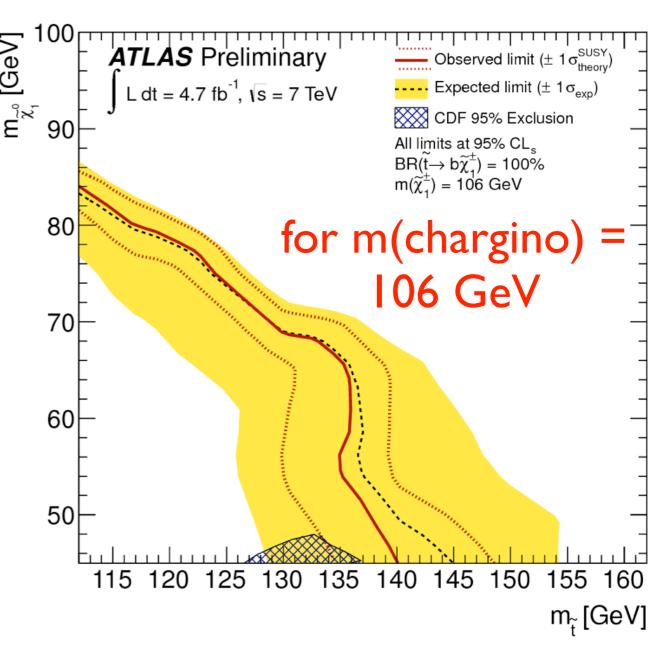
Optimized for  $m(t) \ll m(t)$ 

Signatures: 2 low p<sub>T</sub> leptons, low p<sub>T</sub> b jet (untagged) and  $E_{\rm T}^{\rm miss}$  > 20 GeV

$$\tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm}$$
 BR = 100%  
 $\tilde{\chi}_1^{\pm} \rightarrow W^{(*)}\tilde{\chi}_1^0$ 

Data consistent with SM backgrounds, set limits.







#### Direct light stop search - kinematic search



Same scenario with stop to b chargino, but optimized for  $m(t) \sim m(t)$ .

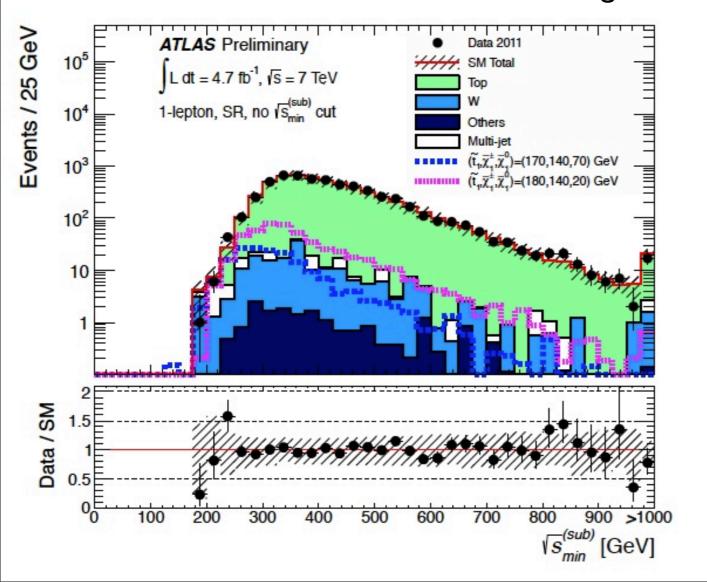
I or 2 leptons, jets are b-tagged to reduce non-top backgrounds.

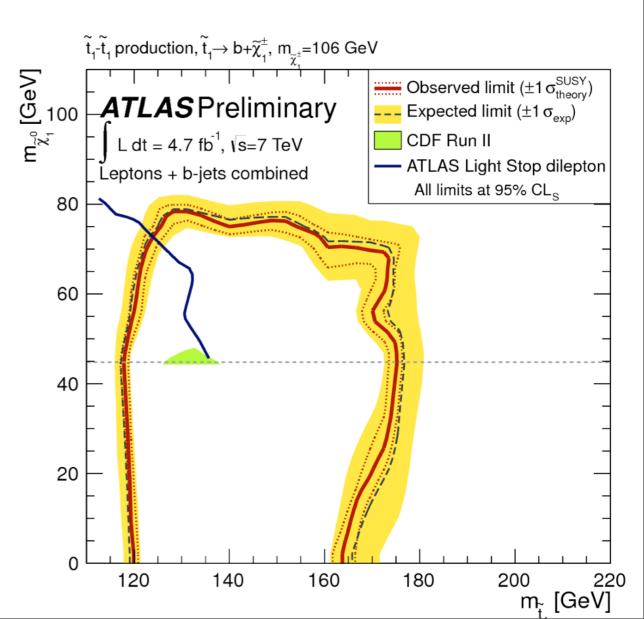
Non-trivial signal selection on kinematic variables:

Invariant mass of top decay products (smaller for stop events)

Mass scale of subsystem of visible and invisible particles from top/stop decay

All channels are consistent with SM backgrounds.







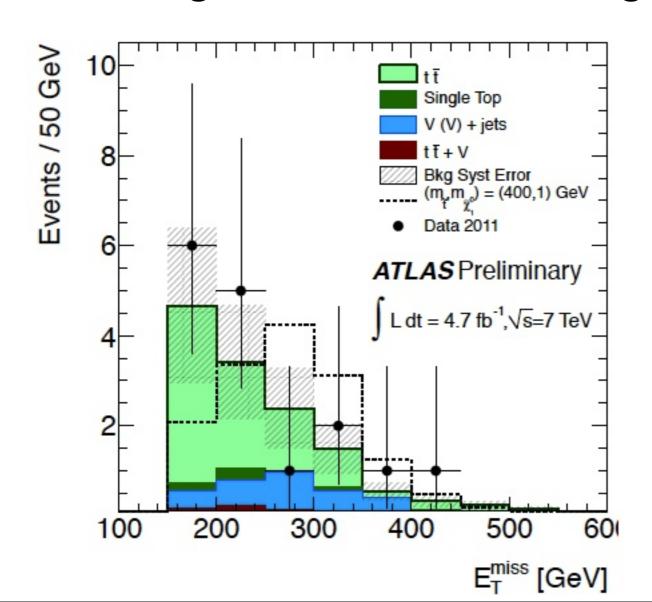
# Direct stop search - 0 lepton

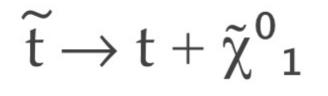
$$m(\tilde{t}) > m(t)$$

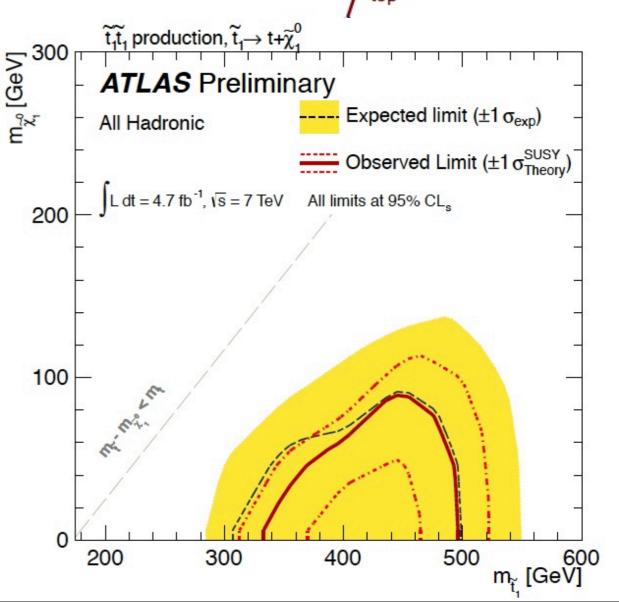
Select 6 jets + 
$$E_{\rm T}^{\rm miss}$$

Background t  $t \rightarrow bjj + bTV$ 

Good agreement with SM background







LSP

top

stop

25 Ge\

Entries /

 $\tilde{t} \rightarrow t + \tilde{\chi}^0_1$ 

 $m(\tilde{t}) > m(t)$ 

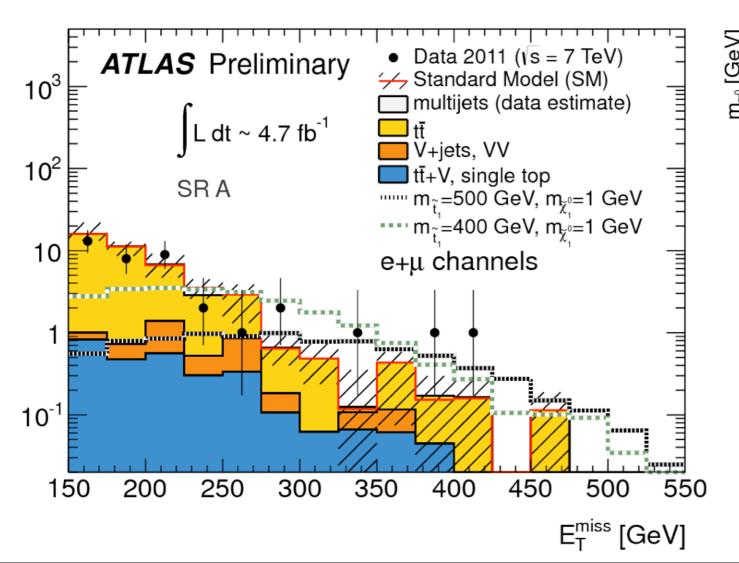
Select: exactly 1 lepton

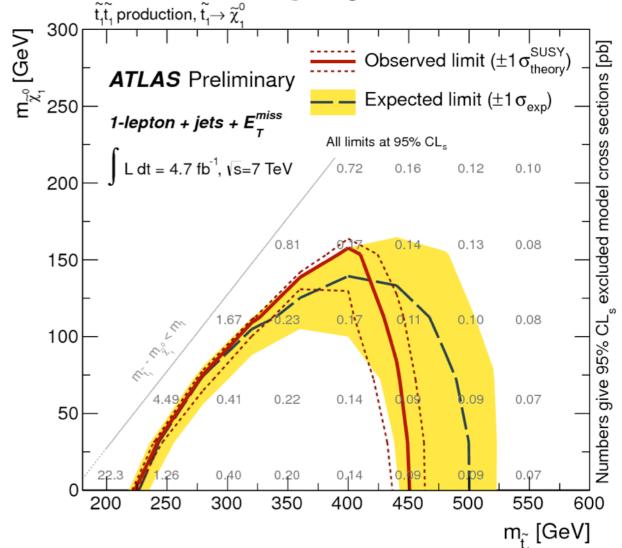
 $\geq$ 4 jets (p<sub>T</sub> > 80, 60, 40, 25 GeV) at least 1 b jet

 $130 \text{ GeV} < m_{iji} < 205 \text{ GeV}$ 

5 signal regions with varying cuts on  $E_{\rm T}^{\rm miss}$  and m<sub>T</sub> to improve sensitivity.

Good agreement with SM background





top

stop

stop



# Direct stop search - 2 lepton

 $m(\tilde{t}) > m(t)$ 

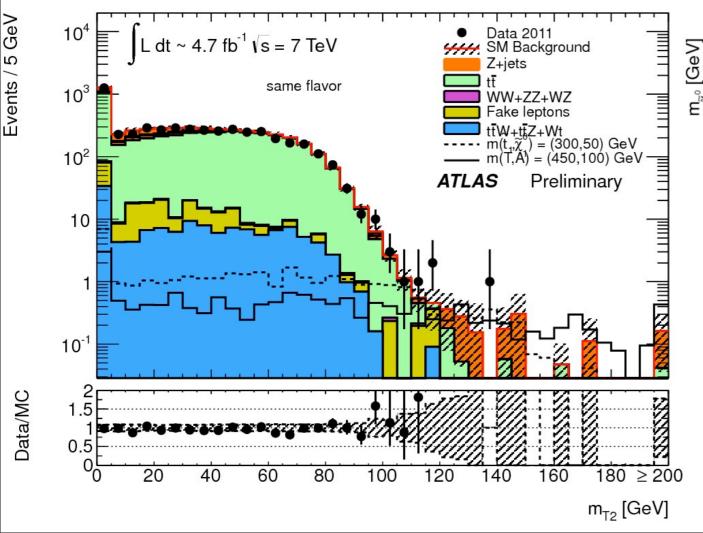
Select: exactly 2 leptons

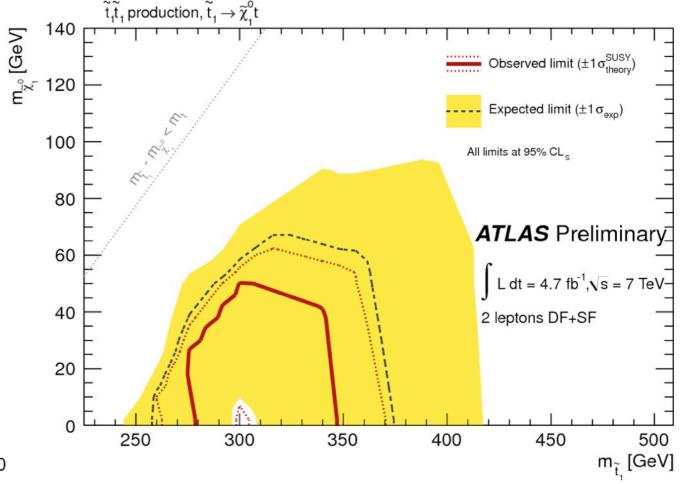
 $\geq$  I jet with p<sub>T</sub> > 50 GeV,  $\geq$  2 jets with p<sub>T</sub> > 25 GeV,  $\geq$  I b jet

$$\mathsf{m}_{\mathsf{T2}} > \mathsf{120~GeV} \quad m_{\mathsf{T2}}(\mathbf{p}_{\mathsf{T}}^{\ell_1}, \mathbf{p}_{\mathsf{T}}^{\ell_2}, \mathbf{p}_{\mathsf{T}}^{\mathsf{miss}}) = \min_{\mathbf{q}_{\mathsf{T}} + \mathbf{r}_{\mathsf{T}} = \mathbf{p}_{\mathsf{T}}^{\mathsf{miss}}} \left\{ \max[\ m_{\mathsf{T}}(\mathbf{p}_{\mathsf{T}}^{\ell_1}, \mathbf{q}_{\mathsf{T}}), m_{\mathsf{T}}(\mathbf{p}_{\mathsf{T}}^{\ell_2}, \mathbf{r}_{\mathsf{T}}) \ ] \right\}$$

if same flavor: 20 GeV  $< m_{II} < 71$  GeV, or  $m_{II} > 111$  GeV

#### Good agreement with SM background





top

top

b-iet

stop

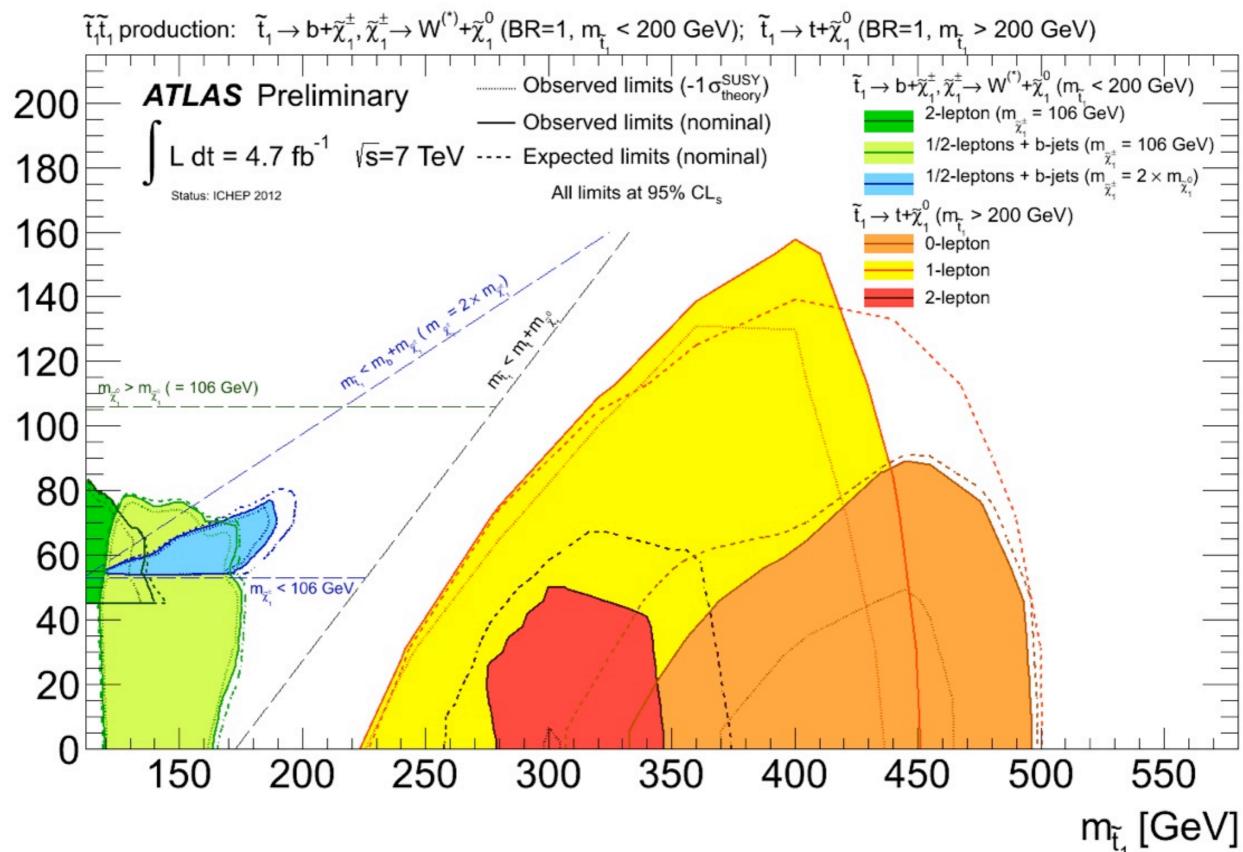
 $\tilde{t} \rightarrow t + \tilde{\chi}^0_1$ 



## Top squark mass limits









# SUSY Limits

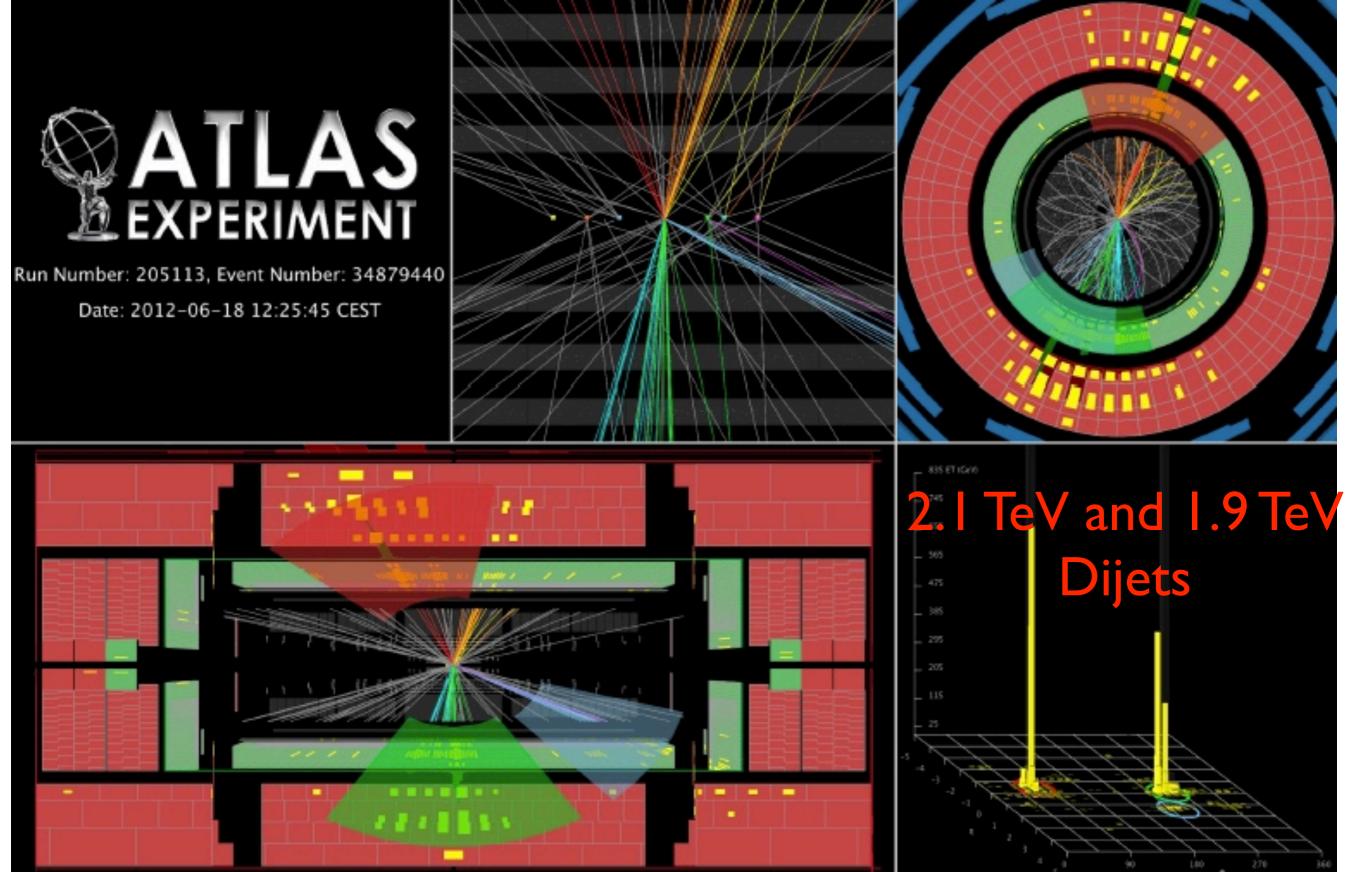


		ATLAS SUSY Searches* - 95% CL Lower Limits (Status: ICHEP 2012)	
	MSUGRA/CMSSM : 0-lep + j's + $E_{T,miss}$	L=4.7 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-033] 1.40 TeV $\widetilde{q} = \widetilde{g}$ mass	
95	MSUGRA/CMSSM : 1-lep + j's + E <sub>T,miss</sub>	L=4.7 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-041] 1.20 TeV $\tilde{q} = \tilde{g}$ mass $\int Ldt = (0.03 - 4.8) \text{ fb}^{-1}$	
searches	MSUGRA/CMSSM : 0-lep + multijets + E <sub>T,miss</sub>	Lim4.7 fb , 7 feV [1206.1760] 840 GeV 9 ff (arge m <sub>0</sub> )	
100	Phono model : 0-lep + J's + E <sub>T,miss</sub>	The state of the s	
	Prieno model : 0-lep + JS + E <sub>T,miss</sub>		
Inclusive	Gluino med. $\chi$ (g $\rightarrow$ qq $\chi$ ): 1-lep + j's + $E_{T,miss}$	3 2	
CE	GMSR : 1-r + i's + F	and the first family and	
7	GMSB: $2-\tau + i^t s + F^{T,miss}$		
	GGM: $vv + F^{T,miss}$		
	7 .hb (virtual h) . 0 lon . h lle . F		
S D	g→bb <sub>2</sub> (virtual b) · 0 lep · 2 b lle · F		
ark	g→bby (virtual b): 0-lep + 3-b-i's + E <sub>T,miss</sub>		
3rd gen. squarks gluino mediated	Garage (virtual t): 1-len + b-i's + E <sub>T,miss</sub>		
F. E	g-try (virtualt): 2-len (SS) + i's + F		
ge	G-tty (virtualt): 0-len + multi-i's + F		
3rd glu	Gatty (virtual t): Olen + 3-hile + F	L=4.7 (b) 7 TeV (ATLAS-CONE-2012-058) 940 GeV Q mass (m(x)) < 50 GeV)	
., .,	g→ttv (realt): 0-len + 3-b-i's + F,miss	$L=4.7 \text{ (b}^{-1}, 7 \text{ TeV (ATLAS-CONF-2012-058)}$ 820 GeV $\widetilde{\text{G}}$ mass $(m_{\widetilde{V}}^{-0}) = 60 \text{ GeV}$	
	$\tilde{h}\tilde{h}, \tilde{h} \rightarrow \tilde{h}\tilde{v}$ : 0-lep + 2-b-lets + $F$	(=2.1 fb <sup>-1</sup> , 7 TeV (1112 3832) 390 GeV b mass (m/c <sup>2</sup> ) < 60 GeV)	
3rd gen. squarks direct production	tt (very light), t→bγ : 2-lep + E.	L=4.7 fb <sup>-1</sup> , 7 TeV [CONF-2012-059] 135 GeV T mass $(m(\tilde{\chi}^0)) = 45 \text{ GeV}$	
ans duci	tt̃ (light), t̃→bỹ²: 1/2-lep + b-iet + E-	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [CONF-2012-TBC] 120-173 GeV $\tilde{t}$ mass $(m(\chi^0) = 45 \text{ GeV})$	
1007	ft (heavy), t→ty : 0-lep + b-jet + F	$I = 4.7 \text{ fb}^{-1}.7 \text{ TeV (ATLAS-CONE-2012-TRC)}$ 380-465 GeV T mass $(m(x^0) = 0)$	
d b	tt (heavy), t→ty : 1-lep + b-iet + E	L=4.7 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-TBC] 230-440 GeV $\tilde{t}$ mass $(m_{\tilde{\chi}}^{(0)}) = 0$	
rd ire	$\widetilde{tt}$ (heavy), $\widetilde{t} \rightarrow t\widetilde{\chi}^0$ : 2-lep + b-jet + $E_{T,miss}$	L=4.7 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-TBC] 298-305 GeV $\widetilde{t}$ mass $(m(\widetilde{\chi}^0) = 0)$	
00	tt (GMSB) : Z(→II) + b-jet + E_	L=2.1 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-036] 310 GeV T mass (115 < m(χ <sub>s</sub> ) < 230 GeV)	
. **	$\widetilde{I_1}\widetilde{I_1}, \widetilde{I} \rightarrow \widetilde{I_2}$ : 2-lep + $E_{\tau \text{ miss}}^{\tau, \text{miss}}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [CONF-2012-TBC] 93-180 GeV $\widetilde{I}$ mass $(\widetilde{\chi}_{*}^{0}=0)$	
EW direct	$\widetilde{\chi}, \widetilde{\chi}, \widetilde{\chi}, \rightarrow \widetilde{l}v(\widetilde{l}\widetilde{v}) \rightarrow lv\widetilde{\chi}$ : 2-lep + $E_{T, miss}$	L=4.7 fb <sup>-1</sup> , 7 TeV [CONF-2012-TBC] 120-330 GeV $\chi^{\pm}$ mass $(m(\chi^0) = 0, m(\tilde{l}, v) = \frac{1}{2}(m(\chi^{\pm}) + m(\chi^0)))$	
9	$\widetilde{\chi}, \widetilde{\chi} \rightarrow 3l( vv)+v+2\widetilde{\chi}, : 3-lep + E_{T,miss}$	L=4.7 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-TBC] 60-500 GeV $\widetilde{\chi}_{\perp}^{\pm}$ mass $(m(\widetilde{\chi}_{\perp}^{\pm}) = m(\widetilde{\chi}_{\perp}^{0}), m(\widetilde{\chi}_{\perp}^{0}) = 0, m(\widetilde{l}, \widetilde{v})$ as above)	
	AMSB : long-lived χ,	L=4.7 fb <sup>-1</sup> , 7 TeV [CF-2012-034] 118 GeV $\tilde{\chi}_{+}^{\pm}$ mass $(1 < \tau(\tilde{\chi}_{+}^{\pm}) < 2 \text{ ns}, 90 \text{ GeV limit in } [0.2,90] \text{ ns})$	
Long-lived particles	Stable g R-hadrons : Full detector	ESTATIO, THE [ATENDOONT-2012-100]	
	Stable b R-hadrons : Full detector		
art			
20	Metastable g R-hadrons : Pixel det. only	L=4.7 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-022] 910 GeV $\widetilde{g}$ mass $(\tau(\widetilde{g}) > 10 \text{ ns})$	
	GMSB : stable $\tilde{\tau}$		
>			
BP			
*****	BC1 RPV : 4-lepton + E <sub>T,miss</sub>		
ē			
Other		Pheno model : O-lep +  s + E	
Spin indep. WIMP interaction: 1/2-jets + E <sub>T,miss</sub> [2=4.7 fb", 7 TeV [ATLAS-CONF-2012-TBC] 548 GeV M <sup>*</sup> Scale (m <sub>χ</sub> < 100 GeV, tensor D9, Diracχ)			



#### **Exotic Searches**







## Dijet Search at 8 TeV

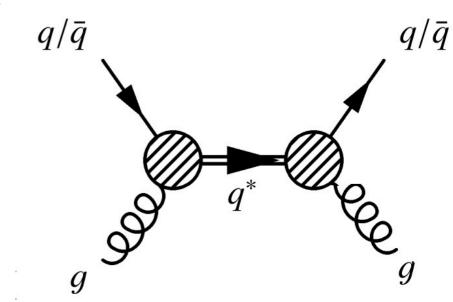


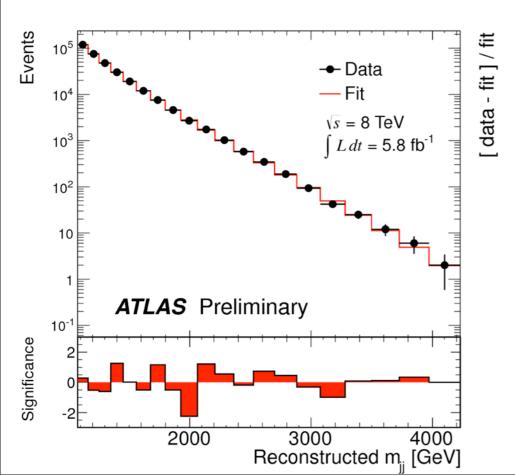
Increased beam energy and parton luminosities → larger sensitivity to excited quarks and other NP.

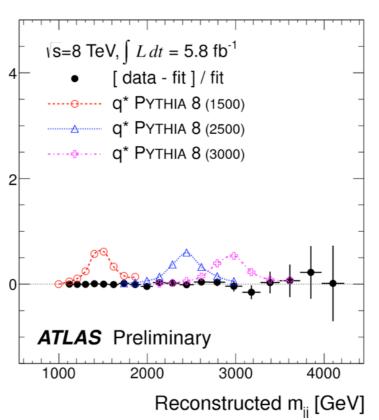
Select 2 jets (jet radius=0.6), |y|<2.8

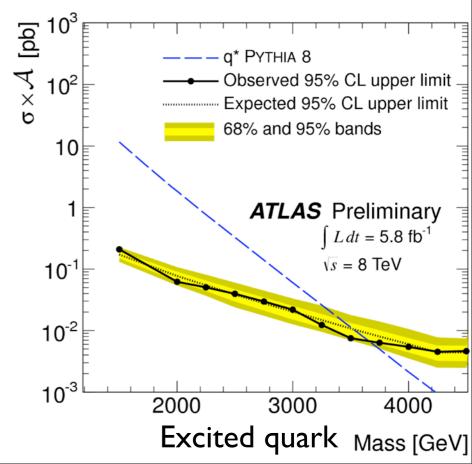
Fit distribution to  $f(x) = p_1(1-x)^{p^2} x^{(p^3 + p^4 \ln x)}$  and search for local deviations.

No evidence of resonances: Limit  $m(q^*)>3.66$  TeV, expected 3.53 TeV (@7 TeV  $m(q^*)>3.35(3.09)$  TeV)











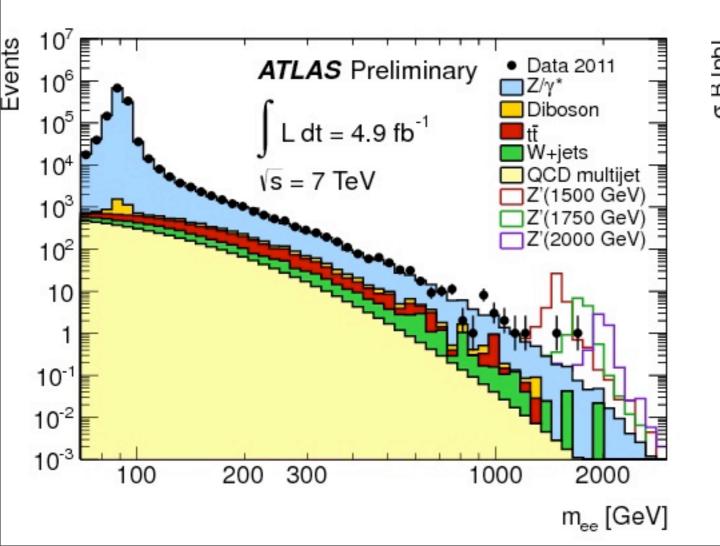
### Dilepton and Z' Search

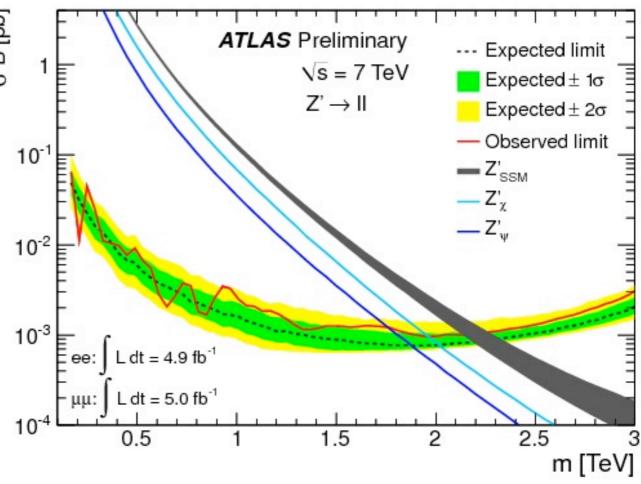


Search for heavy gauge boson Z' in 2 electron and 2 muon channels.

Backgrounds - Irreducible  $Z/\gamma^*$  tail (from MC) data-driven background estimates for QCD multijet (fakes).

Limit set on SSM Z': m(Z') > 2.21 TeV (exp. 2.26 TeV)







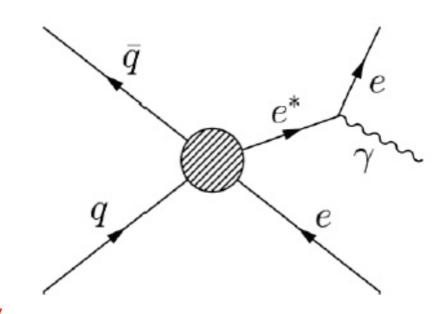
## Dileptons + Photon



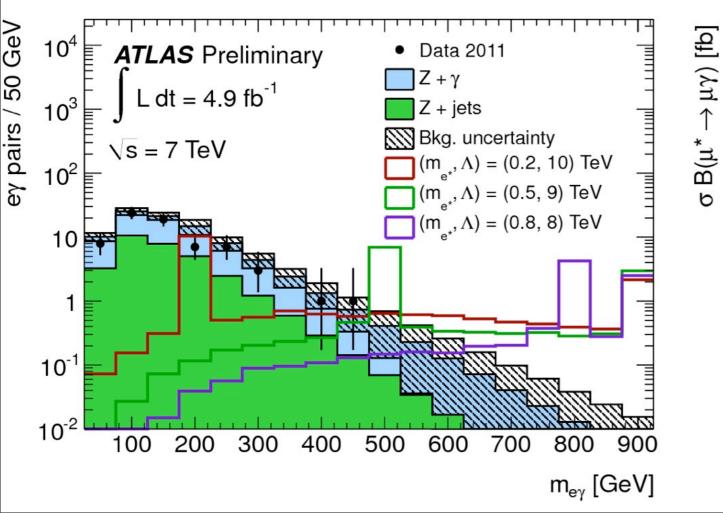
Search for excited leptons.

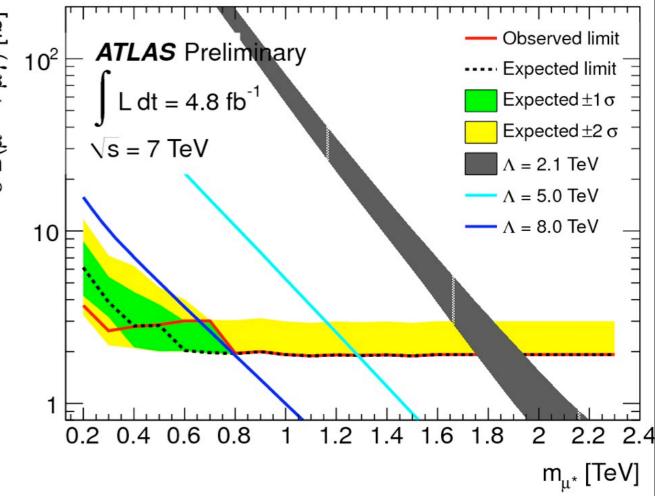
Extend dilepton search by selecting a photon  $p_T>40$  GeV and test for resonance in m(l $\gamma$ ).

No excess in  $m(I\gamma)$  distribution.



Limit at  $\Lambda = m(l^*)$ :  $m(\mu^*) > 1.9 \text{ TeV } m(e^*) > 2.0 \text{ TeV}$ 







# High Mass Diphotons



2 photons provide a clean signal for extra spatial dimensions:

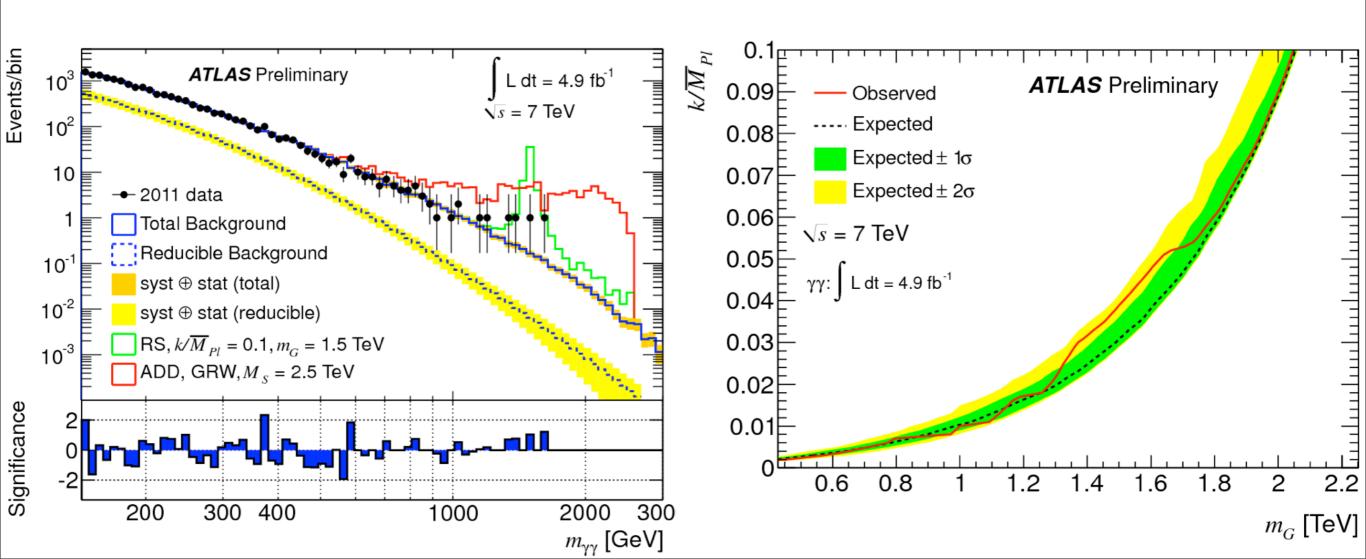
RS gravitons (resonances)

ADD virtual graviton exchange (non-resonant)

Select  $\gamma$  pT > 25 GeV, m( $\gamma\gamma$ ) > 140 GeV

Background largely irreducible, smoothly falling, SM  $\gamma\gamma$ . Fit to  $f(m_{\gamma\gamma}) = p_1 \times (m_{\gamma\gamma})^{p_2 + p_3 \log m\gamma\gamma}$ .

Limits set for RS





# High Mass Diphotons



2 photons provide a clean signal for extra spatial dimensions:

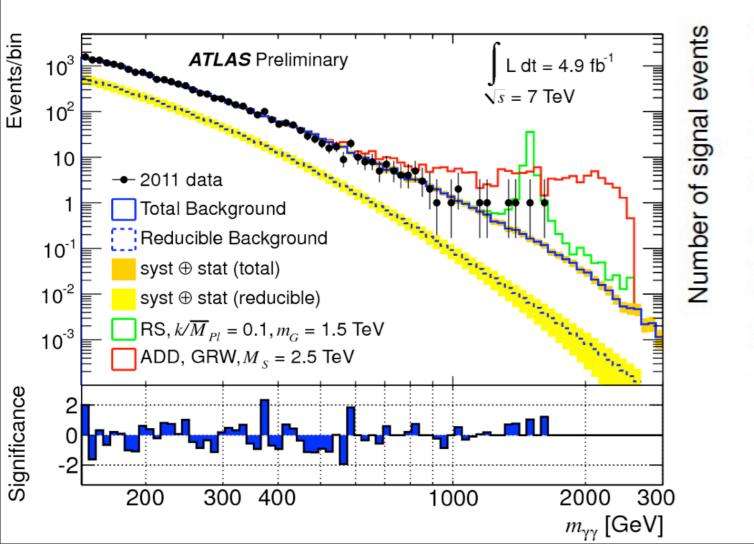
RS gravitons (resonances)

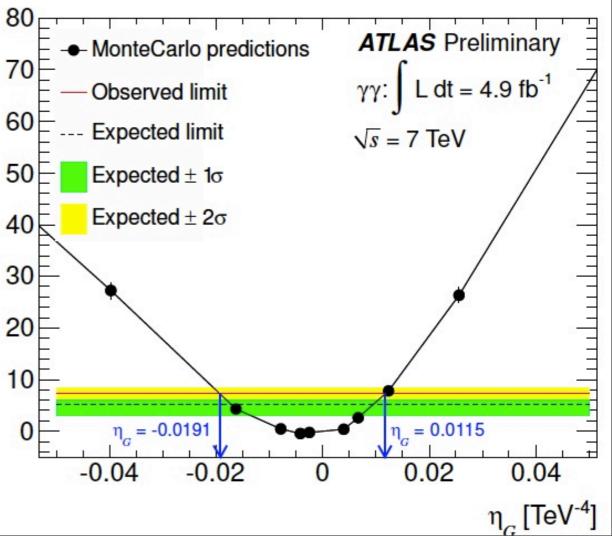
ADD virtual graviton exchange (non-resonant)

Select  $\gamma$  pT > 25 GeV, m( $\gamma\gamma$ ) > 140 GeV

Background largely irreducible, smoothly falling, SM  $\gamma\gamma$ . Fit to  $f(m_{\gamma\gamma}) = p_1 \times (m_{\gamma\gamma})^{p_2 + p_3 \log m\gamma\gamma}$ .

Limits set for RS and ADD  $\eta_G = \mathcal{F}/M_S^4$   $\mathcal{F}^{=}$  related to the number of ED







## Lepton+MET - W' Search

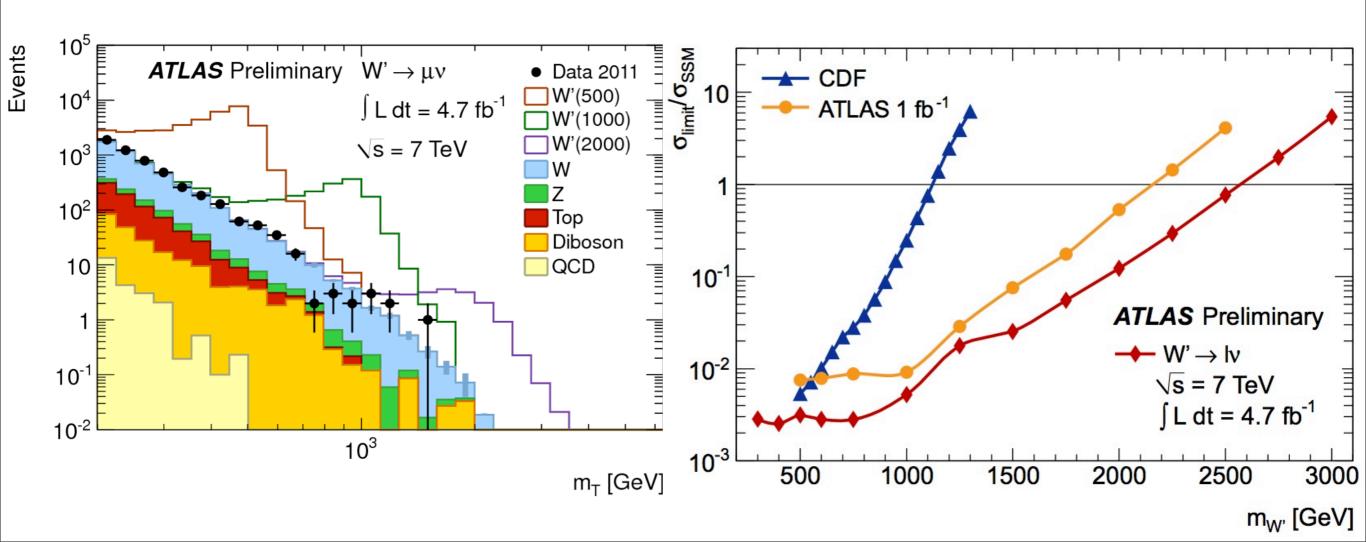


Search for heavy gauge boson W' in eV and  $\mu\nu$  channels.

Select 
$$E_{\mathrm{T}}^{\mathrm{miss}}$$
 > 25 GeV ( $\mu$ ), > 85 GeV (e)

Backgrounds - Primarily irreducible SMW tail. Determined with MC (Pythia 6.421 and reweighted to NNLO with ZWPROD and MSTW2008 PDF).

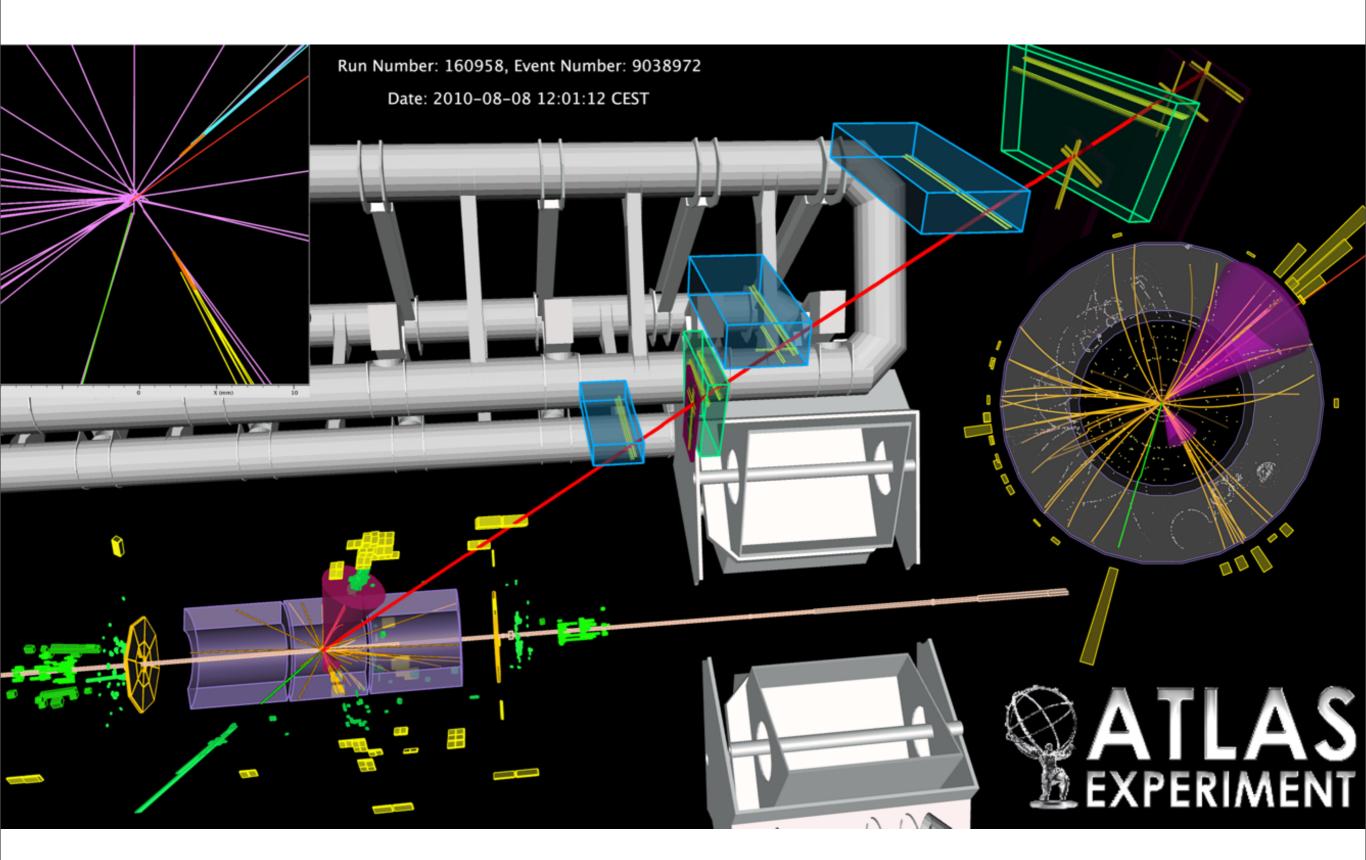
No excess in seen in data. Limit set on SSM W'.





# **Exotic Tops**







#### t t Resonances



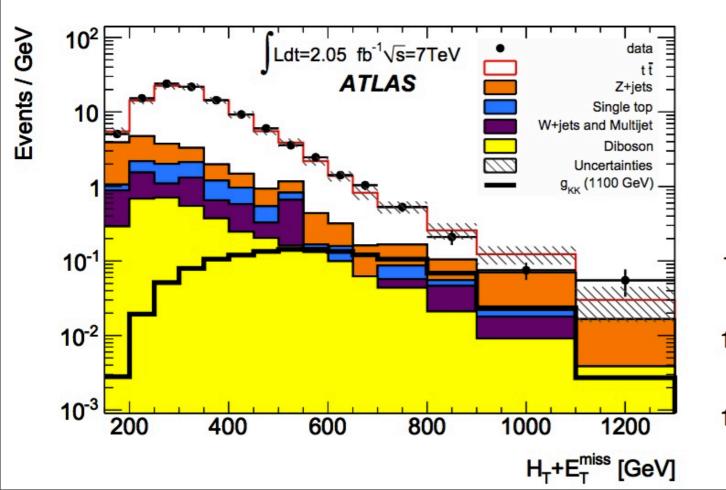
**LHC is a top factory** ( $\sim 10^6$  and counting). New reach in searches for resonances (benchmark top condensate Z') and excesses (RS KK gluon) in t t system.

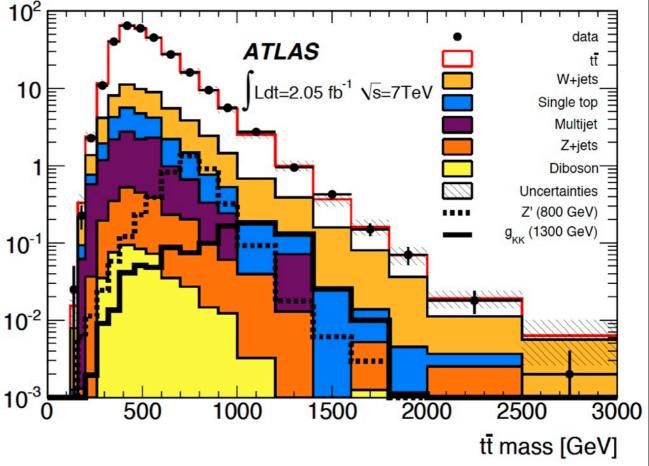
SM t t background dominates: MC@NLO 3.41 + CTEQ6.6 + Photos.

Select: Dilepton (H<sub>T</sub>+  $E_{\rm T}^{\rm miss}$  distribution) - opp. charge,  $\geq 2$  jets, MET > 40 GeV

Semileptonic (m(t t) distribution) - isolated e/ $\mu$ , and I b-tagged jet in either 4 jets or 3 jets if I has m<sub>j</sub>>60 GeV

No excess found. Limits: 500 GeV < m(Z') < 880 GeV and 500 GeV <  $m(g_{KK})$  < 1360 GeV







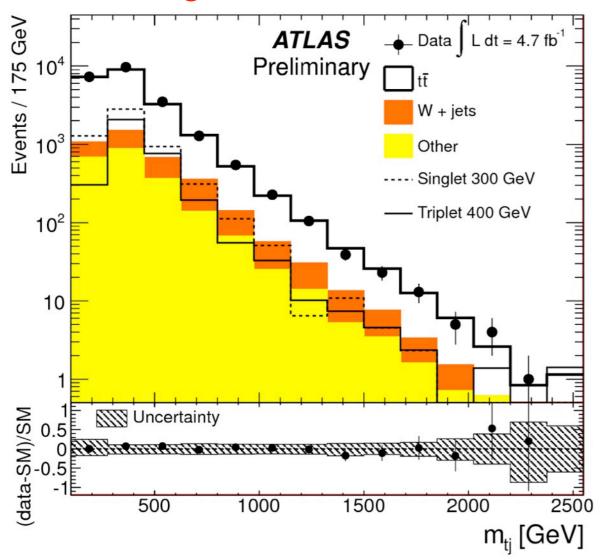
# Top + Jet Resonances

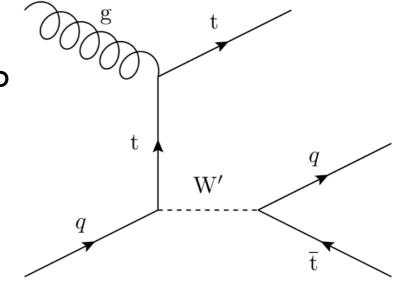


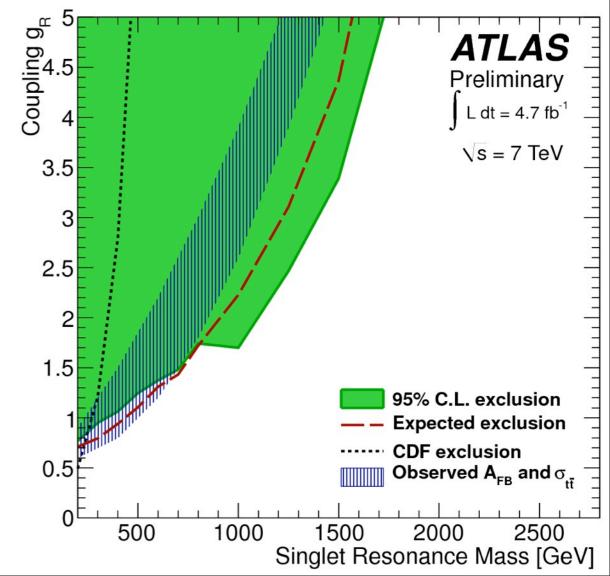
Top flavor violating processes motivated by  $A_{fb}$  measurements. Produce new heavy particle with top, observed as resonant top + jet production in t t system.

Select semileptonic top decay (e/ $\mu$  +  $E_{\rm T}^{\rm miss}$ ) with b-tagged jet,  $\geq$ 5 jets (p<sub>T</sub> >35 GeV).

#### No excess. For $g_R=1$ , lower limit W' < 350 GeV









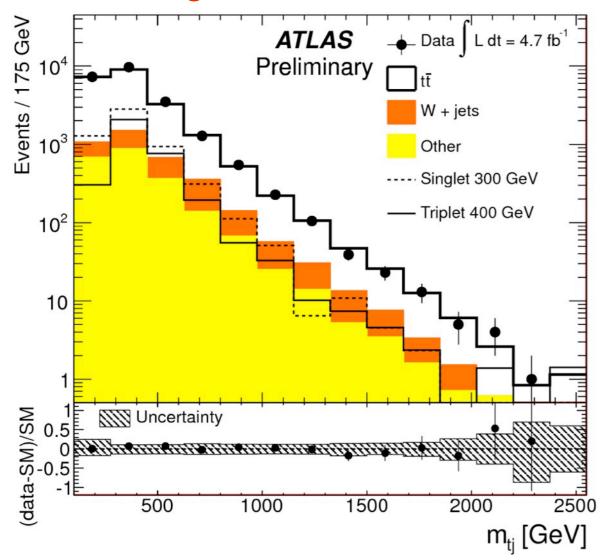
# Top + Jet Resonances

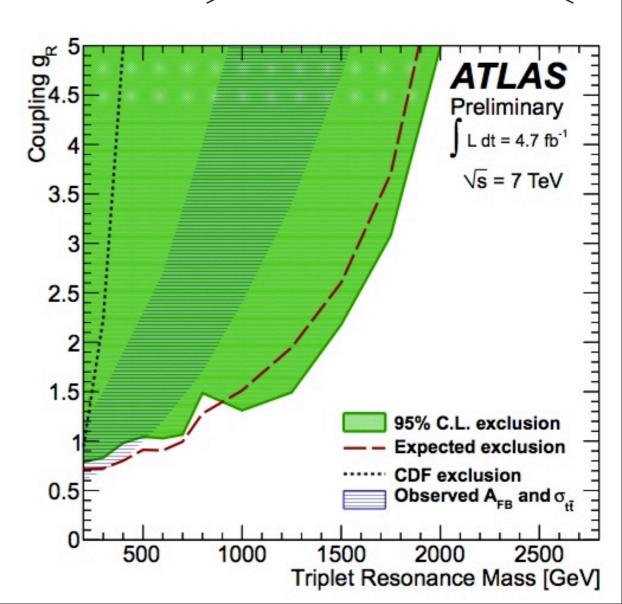


Top flavor violating processes motivated by  $A_{fb}$  measurements. Produce new heavy particle with top, observed as resonant top + jet production in t t system.

Select semileptonic top decay (e/ $\mu$  +  $E_{\rm T}^{\rm miss}$ ) with b-tagged jet,  $\geq$ 5 jets (p<sub>T</sub> >35 GeV).

#### No excess. For $g_R=1$ , lower limit $\Phi < 430$ GeV





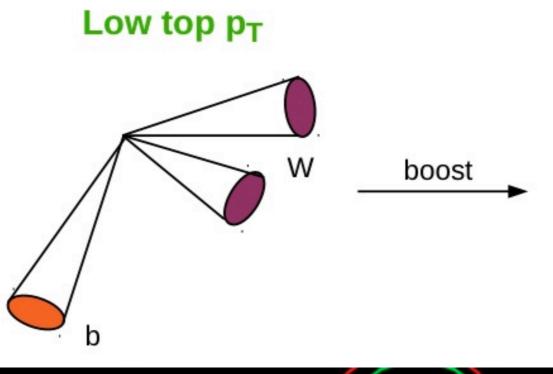


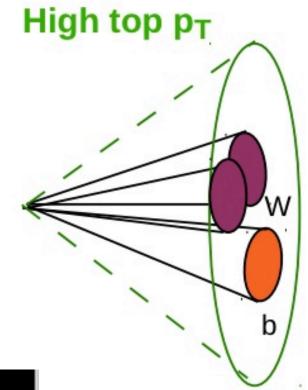
## **Boosted Tops**

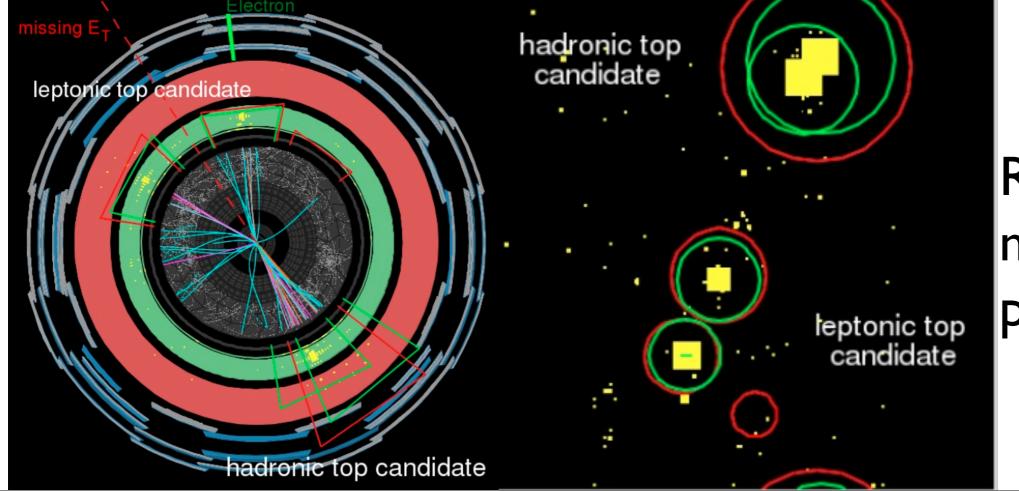


Boosted jets provide a new tool for heavy particle searches.

Jet size R  $\sim 2m_x/p_T$ 







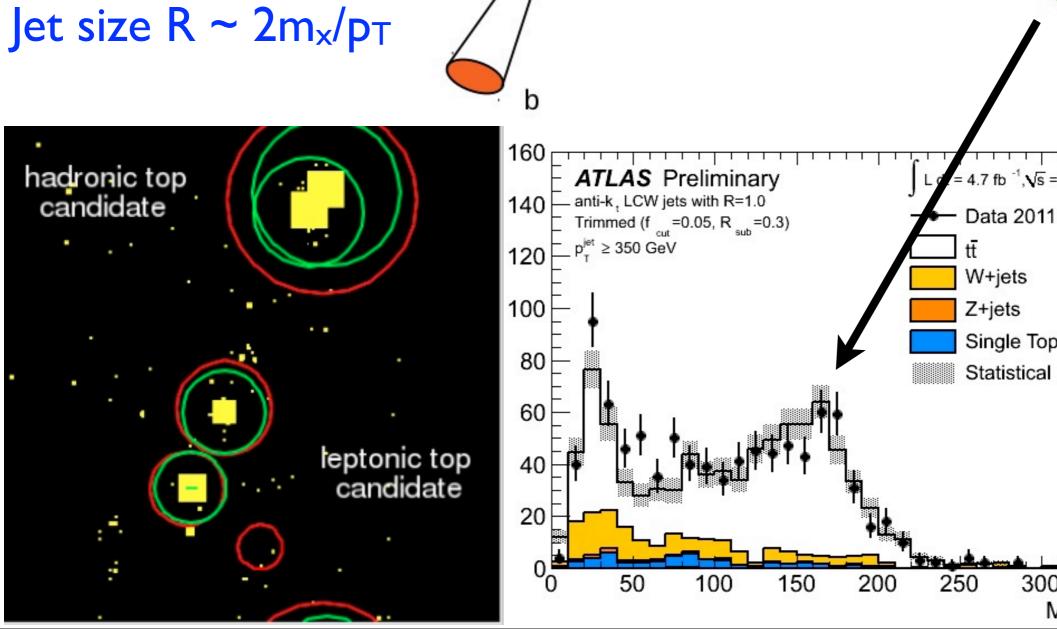
R=1.0  $m_j$ =138 GeV  $p_T$ =641 GeV

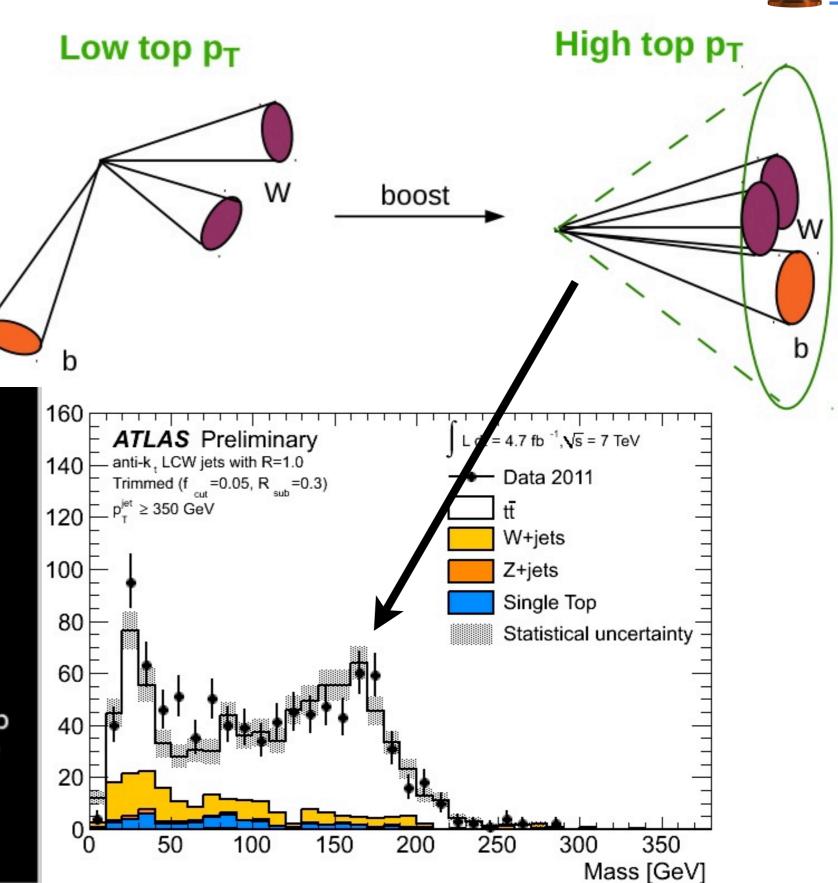


### **Boosted Tops**



Boosted jets provide a new tool for heavy particle searches.







# Boosted t t Resonances

events / GeV



Same leptonic selection as non-

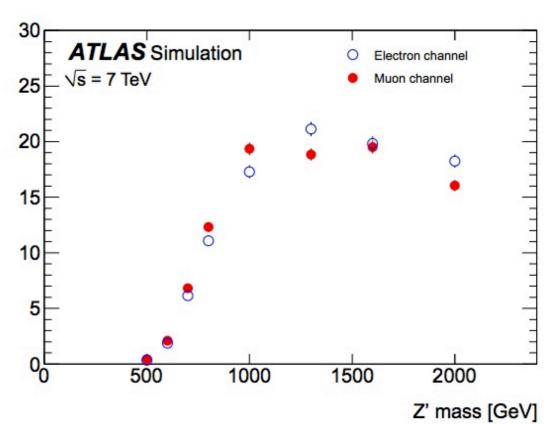
Large-R jet (anti- $K_T$  with R=1.0 with:

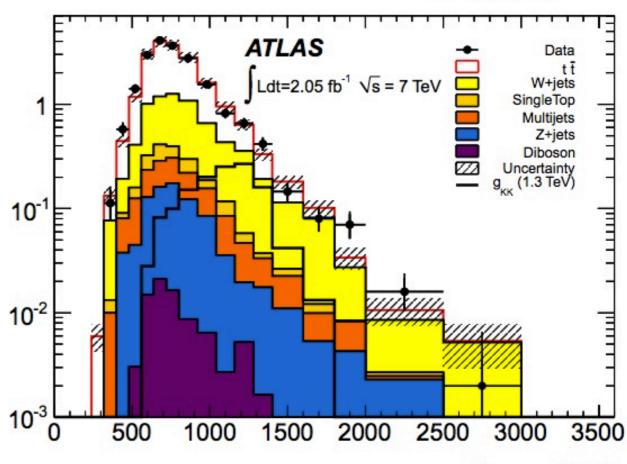
$$p_T > 250 \text{ GeV}$$
  
 $m_J > 100 \text{ GeV}$   
 $\sqrt{d_{12}} > 40 \text{ GeV}$ 

Improved signal efficiency at high masses

No excess found. Limits:

600 GeV < 
$$m(Z')$$
 < 1150 GeV  $m(g_{KK})$  < 1540 GeV

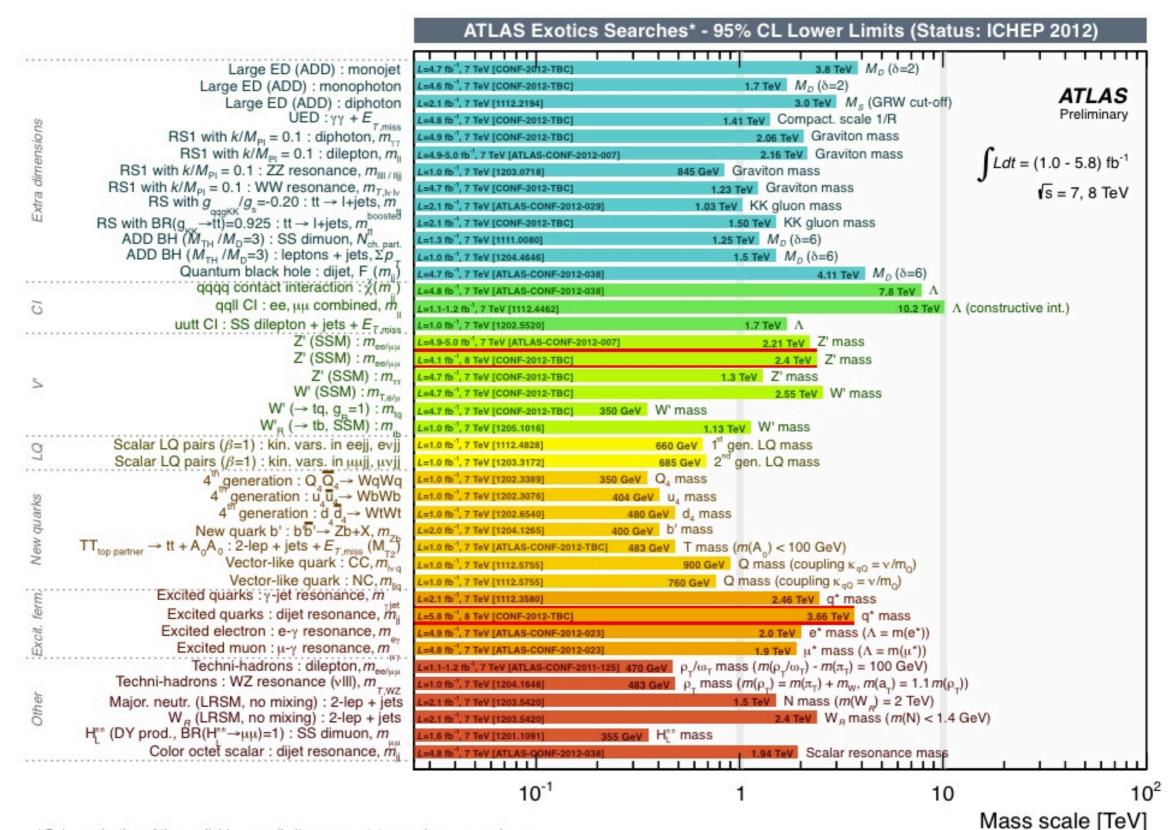






#### **Exotic Limits**







#### Conclusions



We have evidence for a new, narrow resonance at ~126.5 GeV which decays to  $\gamma\gamma$  and  $ZZ^{(*)}$  with  $5\sigma$  certainty.

Results are still preliminary. Measurements of the properties of this resonance are underway.

Proton run extended through December 2012. We will triple (quadruple?) the dataset!





#### Conclusions



SUSY searches probing the 3rd generation(stop) along with many other channels.

Searches for exotic NP with jets, leptons, photons, MET are extending their sensitivity well into the TeV range.

New boosted object signatures are now used in searches for t t resonances. Improvements and additional signatures coming.

